MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

AIRPLANE VIEW OF BURNT AND TIMBERED AREAS IN NORTHERN ONTARIO
(See Article in this issue on The Control of Civil Aviation)

OCTOBER 1923

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 45 October, 1923 Number 10

CONTENTS OF THIS ISSUE

DEPARTMENTAL

ADVERTISING

Price 50 Cents a Copy, $4.00 a year: to Members and Affiliates, 40 cents a Copy, $3.00 a Year. Postage to Canada, 75 Cents Additional; to Foreign Countries $1.50 Additional. Changes of address should be sent to the Society Headquarters.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

H. Sjövall

G. M. Deming

J. C. Smallwood

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C. F. Roby

K. Heindlhofer

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The Control of Civil Aviation

The Necessity of a Recognized System for the Regulation of Air Traffic—International Control Through the International Convention for Air Navigation—Domestic Control as Illustrated by the Operation of the Canadian Air Board Act

By J. A. WILSON,[1] OTTAWA, CANADA

A CENTURY AGO man traveled on foot or on horseback, by mail coach or by ship, and the state took little interest in his health or safety. Today our ships are built, equipped, and navigated to government standards; the operation of our railroads is controlled in the interest of our safety; and our motor cars are licensed and restricted by speed laws and regulations on every side. The growth of this control of transportation by the state provides a fascinating field for study. Shipping and steamboat-inspection acts and the regulation of railway and highway traffic have been forced by the pressure of public opinion and circumstances on unwilling governments. Their action has usually lagged behind what is actually necessary and only the minimum of interference to insure the public safety has been enforced. Such regulations as have been enacted in different parts of the world have been the fruit of experience, and in most cases have been proved necessary under actual working conditions.

The control of aviation has had quite a different history. There has been no such gradual development. The flying machine awaited for many years the invention of an engine light enough to make flight possible. Once this engine was successfully built, flight was accomplished and progress along natural lines proceeded. In the ten years preceding the war there was quiet but steady development of aircraft by firms, individuals, and governments. Each machine built was an improvement on the previous one and it is probable that, had there been no war, the design of aircraft for civil purposes would have been further advanced today. As flying developed there would have been a corresponding growth in air traffic, and necessity would have enforced some measure of state control.

The war of 1914–1919 intervened, and the normal development of aviation ceased. For four years aircraft were considered as weapons of offense and defense only. Billions of dollars were thrown into their manufacture. New engines of greater and still greater power were built. Aircraft design was given a false direction and, though assisted lavishly, was hampered and impeded by the necessity for mass production. Economy of operation, an essential for commercial work, was not considered. When peace came a great development in the aircraft industry had taken place throughout the world. This was not on sound lines from a civil-aviation viewpoint, as there had been no corresponding development of the peacetime use of aircraft. The armistice brought aircraft production to a sudden standstill. No effort had been made to accustom the public to the new form of transportation; no machines intended for the carriage of goods, mails and passengers, nor air traffic systems, had been developed; and no regulations had been framed for the control of the new form of transportation. Aircraft of immense possibilities had been produced, however, and the eyes of the world had been opened to the future of aerial transportation.

The pause which has ensued in the progress of civil aviation has been caused by the lack of two factors essential to the success of commercial aviation. These are the confidence in, and familiarity with, aerial transportation on the part of the public and the creation of aerial transportation systems. Before flying can succeed as a commercial form of transportation these must be created, and some time must yet elapse before their growth overtakes the development of aircraft, hastened unnaturally during the war. To assist this growth the first necessity was the institution of a recognized system for the regulation of air traffic.

International Control

Previous to the war the only step in this direction was the institution, by the International Aeronautical Federation, formed in 1910 with headquarters in France, of a standard for pilots' certificates. These certificates were recognized everywhere and still form the basis of the present-day pilots' qualifications.

Flight is untrammeled by artificial or natural boundaries. The air provides a free and uniform passage everywhere. Aircraft travel with equal ease over land or sea, rivers, plains or mountains. Frontiers or customs barriers mean nothing in the air. Because of this, some form of international control is essential and uniformity in standardization and regulation most desirable. Steps were therefore taken at the Peace Conference, where were gathered together the principal nations of the world, to form a code for the control of civil aviation. A sub-commission of the Peace Conference at Versailles sat during the spring of 1919 and considered the matter in detail. The result was the International Convention for Air Navigation.

The sub-commission which drew up the International Convention was composed of representatives of the allied and associated powers, including the British Empire, the United States, France, Belgium, Italy, and Japan. It was signed by the following powers: Belgium, Bolivia, the British Empire, France, Greece, the United States of America, Brazil, China, Cuba, Ecuador, Guatemala, Italy, Japan, Panama, Poland, Portugal, Roumania, the Kingdom of the Serbs, Croats, and Slovenes, Siam, Czechoslovakia, and Uruguay; and was subsequently ratified by Belgium, Bolivia, Brazil, the British Empire, France, Greece, Japan, Portugal, the Kingdom of the Serbs, Croats, and Slovenes, and Siam.

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Prohibited areas over which aircraft may not fly may be established (Art. 3).

Chapter II—Nationality of Aircraft

Each state shall register and mark its aircraft in accordance with the provision of Annex A to the Convention.

[1] Secretary, Royal Canadian Air Force, Assoc-Mem. Engineering Institute of Canada.

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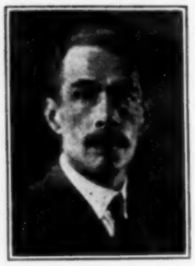
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No aircraft shall be entered on the register of a state unless it belongs wholly to nationals of that state, and further, no incorporated company can be registered as the owner of an aircraft unless it possesses the nationality of the state in which the aircraft is registered; unless the president or chairman of the company and at least two-thirds of the directors possess that nationality; and the company fulfills all other conditions which may be prescribed by the law of the state (Art. 7).

No aircraft may be validly registered in more than one state (Art. 8). States shall exchange information as to the aircraft shown on their official registers (Art. 9).

Chapter III—Certificates of Airworthiness and Competency

Every aircraft engaged in international air navigation shall be provided with a certificate of airworthiness by the state whose nationality it possesses (Art. 11). The qualifications for this certificate are given in Annex B to the Convention.

Personnel operating aircraft shall be properly licensed (Art. 12). The standards of competency required from pilots, navigators, and engineers are laid down in Annex E.

Certificates of airworthiness and competency issued by one state shall be recognized as valid by the other states, but each state has a right to refuse to recognize, for the purpose of flights over its own territory, certificates of competency or licenses granted to one of its own nationals by another contracting state (Art. 13).

No wireless apparatus shall be carried without a special license issued by the state, and further, any aircraft used in public transport and capable of carrying ten or more persons must be equipped with sending and receiving apparatus (Art. 14).

Chapter IV—Admission to Air Navigation above Foreign Territory

Aircraft of a contracting state have the right to cross over the space of another state without landing, but shall follow the route fixed by that state and must land if required to do so at an aerodrome fixed by the latter (Art. 15).

Each state is permitted to establish reservations and restrictions in favor of its national aircraft in connection with the carriage of goods and persons between points in its own territory (Art. 16).

If a state establishes such reservations, other states may retaliate by enforcing similar restrictions against its aircraft, even though the latter do not restrict aircraft of other foreign states which have not enacted such restrictions in favor of their own national aircraft (Art. 17).

Chapter V—Rules to be Observed on Departure, When Under Way, and on Landing

Every aircraft engaged in international navigation shall be provided with certificates of airworthiness and registration. Its crew shall be properly licensed. It shall carry a list of its passengers, bills of lading, and manifest covering its freight, aircraft log books and wireless licenses, if so equipped (Art. 19).

Aircraft in distress shall be entitled to assistance in landing (Art. 22).

The salvage of aircraft wrecked at sea shall be dealt with according to the principles of maritime law in the absence of any other agreement (Art. 23).

Any aerodrome which is open to public use for payment of charges shall be open on the same terms to the use of aircraft of other contracting states (Art. 24).

The observance of the rules of the air and the carrying of lights and signals for night flying are made obligatory (Art. 25).

Chapter VI—Prohibited Transport

The carriage by aircraft of explosives, arms, and munitions of war is forbidden in aircraft engaged in interstate flying (Art. 26). The prohibition and regulation of the use of photographic apparatus in aircraft is permitted to each state (Art. 27). As a measure of public safety the carriage of objects other than those mentioned above may be subject to restriction (Art. 28), and such restrictions shall be applied equally to national and foreign aircraft (Art. 29).

Chapter VII—State Aircraft

State aircraft are divided into two classes, military aircraft (i.e., those commanded by a person in military service—Art. 31), and aircraft exclusively employed in state service, such as posts, customs, police. State aircraft not coming within these two categories shall be treated as private (or commercial) aircraft and shall be subject to the provisions of the Convention (Art. 30).

No military aircraft shall fly over the territory of another state or land thereon without special authorization. If such authorization is enjoyed it shall be entitled to similar privileges as a foreign ship of war (Art. 32).

Chapter VIII—International Commission for Air Navigation

This chapter provides for the creation of a permanent commission for air navigation consisting of two representatives each of the United States of America, France, Italy, and Japan; one representative of Great Britain and one of each of the British Dominions and India; and one representative of each of the other contracting states. Its duties are:

a To receive or make proposals for the amendment of the Convention
b To carry out the duties imposed on it by the Convention
c To amend the provisions of the first seven Annexes to the Convention (particulars given below)
d To collect and communicate to contracting states information of every kind relating to air navigation
e To collect and communicate to all contracting states all information relating to wireless telegraphy, meteorology, and medical science which may be of interest to air navigation
f To insure the publication of maps for air navigation
g To give its opinion on questions which may be submitted to it by contracting states.

The expenses of this Commission shall be borne by the contracting states in proportion to the number of votes at their disposal.

Chapter IX—Final Provisions

The contracting states undertake to coöperate in the collection and dissemination of meteorological information; the publication of standard aeronautical maps; the establishment of a uniform system of ground marks for air stations; and the establishment of facilities for the use of wireless (Art. 35).

The present Convention shall not be construed as preventing the contracting states from concluding special agreements in regard to air navigation provided that notification of these is given to the International Commission (Art. 36).

Provision is made for the arbitration of disputes arising out of the interpretation of the Convention (Art. 37).

In the case of war the provisions of the Convention shall not affect the freedom of action of the contracting states either as belligerents or as neutrals (Art. 38).

States which have not taken part in the war of 1914–1919 shall be permitted to adhere to the present Convention (Art. 41).

The annexes to the Convention are of great importance and lay down in considerable detail the action necessary on the part of the contracting states for the adequate control of civil aviation. They are briefly as follows:

Annex A—The Marking of Aircraft

A system is instituted by which all civil aircraft are marked by groups of five letters. The first letter is known as the nationality mark. These have been allotted as follows:

TABLE OF MARKS TO BE BORNE BY AIRCRAFT

(Annex A of the Convention relating to the regulation of aerial navigation, signed in Paris October 13, 1919, completed by the decisions of the I.C.A.N. dated July 13 and October 25, 1922)

Country	Nationality Mark	Registration Marks
United States of America	N	All combinations made in accordance with the provisions of Section 1(a) of Annex A of the Convention, using a group of 4 letters out of the 26 of the alphabet, each group containing at least one vowel, e.g., ACDJ, PURN.
British Empire	G	
France	F	
Italy	I	
Japan	J	
Hedjaz	A	All combinations made with H as first letter
Nicaragua	A	All combinations made with N as first letter
Lettonia	B	All combinations made with L as first letter
Bolivia	C	All combinations made with B as first letter
Cuba	C	All combinations made with C as first letter
Switzerland	C	All combinations made with H as first letter
Portugal	C	All combinations made with P as first letter
Roumania	C	All combinations made with R as first letter
Uruquay	C	All combinations made with U as first letter
Ecuador	E	All combinations made with E as first letter
Haiti	H	All combinations made with H as first letter
Netherlands	H	All combinations made with N as first letter
Siam	H	All combinations made with S as first letter
Czechoslovakia	S	All combinations made with B as first letter
Guatemala	L	All combinations made with G as first letter
Liberia	L	All combinations made with L as first letter
Luxemburg	L	All combinations made with U as first letter
Spain	M	All combinations made with A, B, C, D, E, F, G, H, I, J, K, L, M, or N as first letter
Brazil	P	All combinations made with B as first letter
Poland	P	All combinations made with P as first letter
Belgium	O	All combinations made with B as first letter
Peru	O	All combinations made with P as first letter
Greece	S	All combinations made with G as first letter
Panama	S	All combinations made with P as first letter
China	X	All combinations made with C as first letter
Honduras	X	All combinations made with H as first letter
Kingdom of the Serbs, Croats, and Slovenes	X	All combinations made with S as first letter

Annex B—Certificates of Airworthiness

Provides for the institution of standards of workmanship material and construction by the Commission. Until these are agreed on each state may set its own standards.

Annex C—Log Books

Provides for the keeping by aircraft of the following books: Journey log, aircraft log, engine log, and a signal log.

Annex D—Rules as to Lights and Signals Rules of the Air

Systems are adapted, generally speaking, from rules for marine navigation, with such alterations as the conditions require.

Annex E—Minimum Qualifications Necessary for Obtaining Certificates as Pilots and Navigators

Lays down in detail the minimum qualifications required by the different classes of personnel engaged in aviation, pilot navigators, and air engineers.

Annex F—International Aeronautical Maps and Ground Markings

Provides for the preparation of a universal system of maps on the International 1 : 1,000,000 scale, and also for a universal system of ground markings for aerodromes.

Annex G—Collection and Dissemination of Meteorological Information

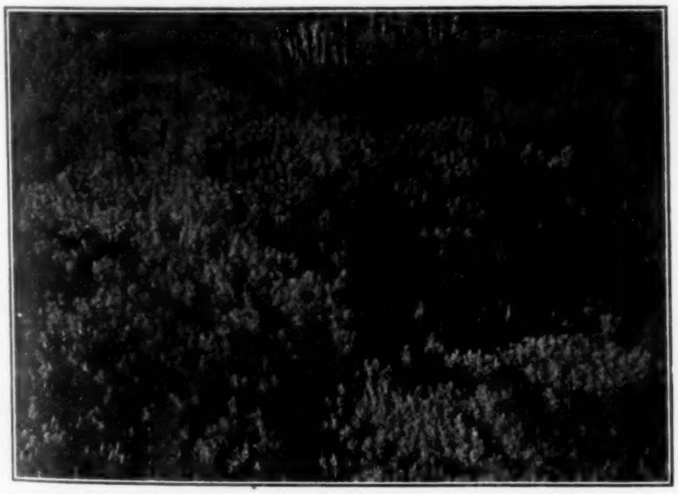
Provides for the collection and dissemination of weather forecasts and the preparation of special reports on meteorology.

Forest Fire in Northern Ontario

Devastation from Fire

Typical Lake and Forest Country in Northern Ontario, Showing Burnt and Timbered Area

Closeup of Portion of Island in Picture to Left, Showing How Timber Types Can Be Distinguished by Airmen



Typical Mixed Forest Country With Coniferous and Deciduous Trees. Note How Easily Each Species Can Be Distinguished While Flying

Hudson Bay Fort, Norway House, in Northern Manitoba, a Remote Outpost Formerly the Center of the Hudson Bay Activities Throughout the North-American Continent

Peace-Time Uses of Aircraft in Canada

As the author points out later in the article, the development of commercial aviation in Canada at the present time is purely as an auxiliary to existing services for forest-fire protection and survey and for work in the more remote parts. There the methods of travel are slow, laborious, and uncertain, and the only competitors are the canoe, pony, and dog train. The photographs on this and the following pages, taken from an airplane, illustrate these peace-time uses of aircraft in Canada.

Annex H—Customs

Deals with customs and the institution of customs aerodromes and regulations applicable to the import and export of goods by air.

Did space permit there are many points in the Convention which could be further elaborated to good purpose. This is especially true of the annexes, which are of the greatest value and provide, on the whole, a thoroughly sound basis for the control of civil aviation and for systems to collect and disseminate information not only on aviation but on the subjects of wireless communication and meteorology, without which the conduct of international flying cannot be efficiently conducted. The limits of this paper, however, will not permit of this.

The International Commission formed under Chapter VIII of the Convention is now functioning. It has held three general meetings. Committees have been formed to deal with the duties imposed on it by the Convention in relation to the preparation of aeronautical maps, the operation of wireless in connection with aviation, medical standards for air personnel, standards of airworthiness for machines, and other kindred subjects.

The Commission has already under consideration various modifications and amendments to the Convention which experience has proved necessary. As aviation develops this will continue to be the case. In the Commission the world has now a permanent body for the consideration of such questions. If properly used and directed it will insure the maintenance of universal aviation standards, adequate for their purpose, and in addition a body for their revision as new conditions arise.

Domestic Control

Having considered the question of international control, we pass on to the question of domestic control by each state. Canadian conditions are naturally those most familiar to the author and will therefore be dealt with to illustrate the subject. Similar principles to those proved sound in actual practice in Canada will hold good elsewhere.

The Air Board Act, passed by the Canadian Parliament in June, 1919, instituted an Air Board presided over by a Minister of the Crown having full powers to deal with aeronautics in all its phases. Under legislation passed in 1922 for the creation of a Department of National Defense, the powers of the Air Board are vested in the Minister of Defense. The control of aeronautics, however, remains undivided.

Under Section 3 of the Air Board Act the following duties in regard to the control of civil aviation are laid on the Board:

a To supervise all matters connected with aeronautics
b To study the development of aeronautics in Canada and in other countries, and to undertake such technical research as may be requisite for the development of aeronautics, and to coöperate with other institutions in carrying out such research
f To prescribe aerial routes
h To take such action as may be necessary to secure, by international regulation or otherwise, the rights of His Majesty in respect of His Government of Canada in international air routes
k To investigate, examine, and report on all proposals for the institution of commercial air services within Canada or the limits of the territorial waters of Canada.

Typical Forest and Lake Country in Northern Manitoba and Saskatchewan
(This and similar pictures have been used for mapping these regions by means of the grid method.)

Under Section 4 the Board is given power to "regulate and control aerial navigation over Canada and the territorial waters of Canada," and in particular, but not to restrict the generality of the foregoing terms, it may, with the approval aforesaid, make regulations with respect to

a Licensing of pilots and other persons engaged in the navigation of aircraft, and the suspension and revocation of such licenses
b The registration, identification, inspection, certification, and licensing of all aircraft
c The licensing, inspection, and regulation of all aerodromes and air stations
d The conditions under which aircraft may be used for carrying goods, mails, and passengers, or for the operation of any commercial service whatsoever, and the licensing of any such services
e The conditions under which goods, mails, and passengers may be imported and exported in aircraft into or from Canada or within the limits of the territorial waters of Canada, or may be transported over any part of such territory
f The prohibition of navigation of aircraft over such areas as may be prescribed, either at all times or at such times or on such occasions only as may be specified in the regulation, and either absolutely or subject to such exceptions or conditions as may be so specified
g The areas within which aircraft coming from any places outside of

Canada are to land, and the conditions to be complied with by any such aircraft

h Aerial routes, their use and control

i The institution and enforcement of such laws, rules, and regulations as may be deemed necessary for the safe and proper navigation of aircraft in Canada or within the limits of the territorial waters of Canada.

Under clause 2 of this section, "any person guilty of violating the provisions of any such regulation shall be liable, on summary conviction, to a fine not exceeding one thousand dollars; or to imprisonment for any term not exceeding six months, or to both fine and imprisonment."

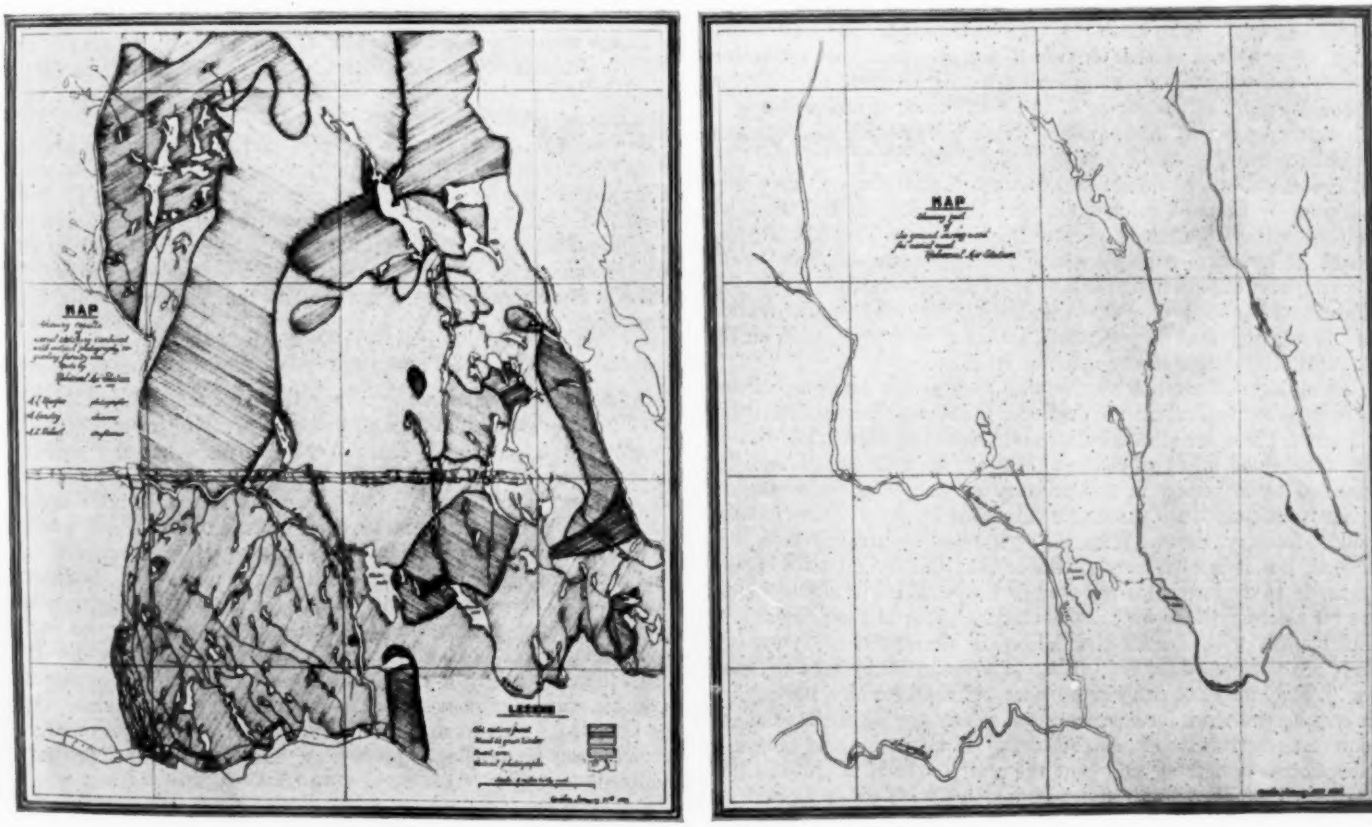
Section 3 provides for the enactment of the necessary regulations as follows:

All regulations enacted under the provisions of this Act shall be published in the *Canada Gazette*, and, upon being so published, shall have the same force in law as if they formed part of this Act. Such regulations shall be laid before both Houses of Parliament if Parliament is then sitting, and if Parliament is not then sitting, then within ten days after the next meeting thereof.

To illustrate the working of the system, let it be supposed that a company is being formed for the conduct of commercial aviation in this country. They apply to the State Department for incorporation. Those terms of their charter which concern the conduct of air services are referred for advice to the Department of National Defense.

Air Harbors

As no aircraft may be operated except from licensed air harbors, the company leases or buys a site for its air harbor, and applies for its license. An inspector visits the site and reports on its suitability. The points given special attention are the wind conditions and, in the case of a seaplane station, its exposure to heavy seas; the area available for taking off and alighting; whether it is surrounded by buildings or natural objects likely to obstruct the taking off or landing of machines; the surface of the ground and the nature of the soil. If the site is found satisfactory a license is issued. Air harbors have been divided into the following classes:



Illustrating the Results of Sketching from the Air in Mapping Forest Types

(The left-hand map shows supplementary topographical details added to original map, which showed only main water courses and, in addition, the nature of the forest in the district. Extensive use of this method is being made for exploratory mapping of timber resources in Canada.)

It will be seen from the above that adequate powers for the control of civil aviation exist in Canada.

Following out the duties imposed on the Board by this legislation, an order-in-council was passed on December 31, 1919, approving and promulgating the Canada Air Regulations 1920, which cover in detail the air law of Canada and provide a complete set of rules which after three years' experience have proved in practice to be fundamentally sound, though in minor details they may require modification and amendment. These regulations conform in essentials to the International Convention, and the ideas and standards laid down in it are their basis. Diversions on minor points were found necessary to meet Canadian conditions. These are now being taken up through the Commission for adjustment and every effort will be made to hold a uniform code with other states. This is considered of vital importance to the future of international flying.

The administration of the Canadian Air Regulations is carried out by the Department of National Defense through the Controller of Civil Aviation.

I Airship harbors (i.e., for lighter-than-air machines)

II Aerodromes and seaplane stations, subdivided as follows:

- *a* Public air harbors open day and night
- *b* Public air harbors open by day only (These are open to all traffic on payment of approved landing and storage charges)
- *c* Public customs air harbors open by day and night
- *d* Public customs air harbors open by day only (Recognized by the customs and immigration authorities as ports of entry from foreign countries)
- *e* Commercial air harbors
- *f* Commercial customs air harbors (Limited for the use of the licensees only).

A distinctive ground marking is allotted, depending on the class within which the air harbor comes. A simple system of markings has been devised which show not only the class of air harbor but its size under five divisions, i.e., under 300 yd., 300 to 400 yd., 400 to 600 yd., 600 to 800 yd., aerodromes over 800 yd. and all seaplane stations.

Airworthiness of Machines

The next step is the licensing for airworthiness of the machines. If these are of a type which has been previously certified as airworthy, under the terms of the International Convention in Canada or in any other country, all that is necessary is an inspection by a competent person to ascertain whether they comply in material, workmanship, and construction with the type, and whether they are properly rigged in all respects and their engines and equipment are in good condition. They must also be provided with the necessary instruments for safe flying and log books for the aircraft and engine which show their history. If the inspector is satisfied that the conditions of the Air Regulations have been complied with, the licenses are issued. If any aircraft is of a type not previously certified as airworthy, detailed drawings of it must be submitted to the Department. These are carefully examined by the technical staff, the factors of safety are calculated, and the design analyzed with reference to its stability, flying qualities, safety from fire, etc. This examination is of the greatest importance and it is essential that it should be thoroughly done by a fully competent and experienced staff. The issue of a type certificate by one state means that all machines of that design, if properly built, are recognized as airworthy by all states adhering to the Convention. Mutual recognition by all countries of the certificates of airworthiness of aircraft engaged in international flying is essential, and common standards are therefore desirable.

The standards of design and factors of safety which have been adopted by Canada, in common with Great Britain and the other self-governing dominions of the British commonwealth, are the result of practical experience and research extending over many years. The exceptional freedom from flying accidents in Canada and Great Britain proves that they are sufficient to insure the safety of the machine and its occupants, in so far as that depends on the strength and design of the machine itself.

As all aircraft are not commercial, a digression must be allowed here from our typical case to deal with the airworthiness of the other classes. These are state aircraft and private aircraft. The former are subdivided into two classes: Military aircraft, i.e., those commanded by a person in the military service; and state aircraft, those belonging to the state and employed for its civil uses (postal, police, forestry, etc.). With the first class we are not here concerned, but it is obviously desirable that the second class should be made to conform in every way to the standard of airworthiness set for commercial aircraft and should, in so far as their duties permit, comply with the Air Regulations in all respects. Private aircraft are those used for the private pleasure or business of any person. They may not carry passengers or freight for hire, nor engage in commercial work for compensation of any kind. Such machines require no certificate of airworthiness. It might be held that this exception is dangerous and that the state neglects its duty in not insisting that all aircraft flown should be certified as airworthy. On the other hand, a too rigorous insistence on set standards and types might cramp and hamper the design of new types and make experimental and research work difficult. This exception is made to encourage such work so that the development of new types may be carried on unhampered by restrictions.

Flying Personnel

The next problem before our company is the licensing of its personnel. These are divided into two main classes, flying and ground. The flying personnel are subdivided into two classes, pilots and navigators, each of which is subdivided in accordance with the type of machine that they are qualified to fly. Lighter-than-aircraft pilots are classed as balloon pilots and airship officer pilots, the latter receiving first-, second-, and third-class certificates in accordance with the size of the airship. As the development of lighter-than-aircraft is still in its infancy it is not necessary to go into further details as to the qualifications required for this class of work.

Heavier-than-air-machine pilots are subdivided into private and commercial pilots. The certificate for the former does not authorize its holder to fly for hire, but the candidate must pass a medical examination once each year and a flying test before it is issued. Commercial pilots' certificates are of two classes, for land machines and for water machines. Each class is subdivided into

a Light machines—maximum safe load, including fuel and oil, 1000 lb. or less

b Medium machines—maximum safe load, including fuel and oil, more than 1000 and less than 3000 lb.

c Heavy machines—maximum safe load, including fuel and oil, 3000 lb. or more.

Certificates are granted subject to the holder's passing a medical examination at least every six months. The flying tests include not only tests of skill as a pilot, but a cross-country flight of not less than 175 miles to insure the pilot's capacity for cross-country work and a night-flight test. All classes of pilots are required to pass an examination on the construction, maintenance, and functions of the aircraft, its engine and accessories. They must also have full knowledge of the rules as to lights and signals, rules of the air, and the conduct of traffic in the vicinity of air harbors. They must have a good knowledge of the Canadian Air Regulations and the International Joint Convention for Air Navigation and, in addition, of map reading, orientation, location of position, and elementary meteorology.

The examinations and tests are all of a practical nature and are set by practical flying men with a view to ascertaining as far as possible the actual suitability of the candidate for his work as a commercial pilot.

Air navigators' certificates are provided for, but in the present state of development of aviation have not been found necessary. They are intended for use in the case of large machines of great range, when the navigation of the aircraft will be undertaken by a different officer from the pilot. They are largely based on the master mariner's certificate, modified to meet the new conditions, and will in time undoubtedly fill an important place in aerial transportation.

Ground Personnel—Air Engineers

On this class is thrown the responsibility of maintaining the aircraft in airworthy condition after a certificate of airworthiness is granted by an inspector. The Government inspects every machine at least once a year, but the day-to-day maintenance rests with the air engineer. No aircraft may be operated in this country unless a licensed air engineer is employed to maintain it. This is a very necessary precaution as many present-day pilots, especially the younger men, are careless in regard to the maintenance of their machines. There is nothing to prevent a pilot from qualifying as an air engineer and maintaining his own machine, and in most cases commercial pilots hold the double qualifications. Every day before a flight is taken the air engineer must certify that the machine is, in his opinion, airworthy. The company can now operate with the knowledge that in so far as the state can provide, its premises are suitable, its machines airworthy, and its personnel properly qualified.

Operations

In Canada there has been practically no development of passenger, mail, or express services. Until these are successful in countries where the population is denser, the need for quick transportation more urgent, and the physical difficulties less, it has been felt that these can wait. Our principal and most promising development has been in connection with work in the remoter parts of the country where the methods of travel are slow, laborious, and uncertain, and the only competitors are the canoe, pony, or dog train. There exists a vast field for this class of work in Canada and already a start is being made to develop commercial aviation as an auxiliary to existing services for forest fire protection and survey, the natural immediate outlets for commercial aviation in Canada. Mail and passenger services will follow in time.

Interstate flying between Canada and the United States is commencing between the large cities on either side of the international boundary. The Canadian regulations allow for the entry of machines of American nationality engaged in this traffic. Such machines may only land at an air harbor approved by the customs and immigration authorities. These authorities have shown themselves most anxious to coöperate in the development of air traffic and impose no unnecessary restrictions.

(Continued on page 613)

Blended Fuels for Automotive Engines

A Study of Mixtures of Other Fuels with Gasoline with Respect to the Power They Develop, Cost per Horsepower-Hour, and Overall Economy, and Their Value as a Means of Relieving Gasoline Shortage

By JULIAN C. SMALLWOOD,[1] BALTIMORE, MD.

BLENDED FUELS, as the term is used in this paper, are not substitutes for gasoline but mixtures of other fuels with gasoline, the purpose of which is to make a superior, cheaper, or more salable product. There is one mixed fuel, namely, benzol and alcohol, which does not fall in this classification, although it may in the future have considerable importance. Such a fuel is a substitute for gasoline, but since there is no large organization interested in its manufacture and distribution, the supply of benzol is limited, and the cost of alcohol compared with gasoline at present is high, it seems unlikely that this fuel will have much prominence in the near future.

Gasoline blends, listed in the order of their importance, are benzol, kerosene, alcohol, and ether, these being mixed with the gasoline in various proportions. Since benzol is obtained chiefly as a by-product in coke ovens, distribution centers of benzol-blended gasoline are to be found exclusively in cities which support industries requiring coke ovens on a large scale. Even when the blended fuel requires as little as 10 per cent of benzol, there is not enough yield to support distribution beyond a very limited radius. The whole subject is consequently now of only local importance, but as the sources of benzol increase, more and more use will be made of this very desirable fuel.

Considering the present situation, owners and operators of motor vehicles on a small or large scale, in localities where blended fuels are obtainable, must decide upon the relative merits of such fuels at a somewhat higher price per gallon as compared with those of so-called "straight" gasoline. Putting aside all psychological reactions, which form a large part in "results" obtained by individuals during road tests necessarily of inaccurate character, an impartial study must be made of the following claims:

1 That blended fuels give greater power
2 That they give greater economy in fuel consumption
3 That they give better operation of engine
4 That the total cost of operation with blended fuels is less than with gasoline in spite of the higher price per gallon
5 That blended fuels afford a valuable means of relieving gasoline stringency.

In order to make this study thorough, some of the physical properties of three fuels will first be considered, as follows:

	Gasoline	Commercial Benzol	Ethyl Alcohol
Lower heating value, B.t.u. per lb.	18,000	17,300	10,800
Gravity, deg. Baumé	60	30	44
Specific gravity	0.737	0.874	0.806
Weight per gal., lb.	6.13	7.28	6.71
Lower heating value, B.t.u. per gal.	110,500	126,000	72,400
End point on distillation curve, deg. fahr.	437	250	172
Air required for theoretical combustion per lb. of fuel, lb.	15	13.3	8.6
Heating value, B.t.u. per lb. of combustible mixture (air and fuel)	1125	1209	1125

The lower heating value is quoted instead of the higher because under no circumstances can the modern gasoline engine make available the heat content of the water of combustion.

Pure benzol, C_6H_6, being a single chemical compound, has a horizontal distillation curve at 176 deg. fahr. Owing to the impurities in the commercial product (toluol, xylol, etc.) its curve rises at about 90 per cent and 176 deg. to the value tabulated.

It will be observed from the table that, although the heating value of benzol in B.t.u. per lb. is less than that for gasoline, its greater density reverses this relation when based on the gallon. Since these fuels are *sold* by the gallon, this appears as a point in favor of benzol.

The last item in the table is obtained by dividing the first item by the number of pounds of combustible mixture; e.g., for gasoline, $18{,}000 \div (1 + 15) = 1125$. This result is the real criterion of power capacity. In general a rich fuel requires more air for combustion. The more air required, the less fuel can be used per cycle in a cylinder of given dimensions. This offsets the apparent advantage of a high-heating-value fuel in so far as maximum engine capacity is concerned. Although the heating value of benzol is 14 per cent greater if based on the gallon, it is only 7 per cent in excess if based on the charge.

Power

From the above consideration it would appear that an engine using unmixed commercial benzol could not develop more than 7 per cent more power than one using straight gasoline. Certainly it cannot be shown on a basis of heating values that a gasoline blended with 10 or 20 per cent of benzol would give an appreciable increment of power over gasoline.

It has been argued that the blended fuel has a lower end point than gasoline. This is undoubtedly the case. Report No. 47 of the National Advisory Committee on Aeronautics shows distillation curves, obtained by the Bureau of Standards, for export aviation gasoline with an end point of 392 deg. fahr., and for gasoline blended with 20 per cent of benzol with a resulting end point of 290 deg. fahr. From this it might be concluded that the greater volatility obtained with the blended fuel will cause better combustion and increased power. It must be remembered, however, that the present-day automobile engine is very well adapted to take care of low end points by hot spots and similar devices. The report quoted above also states that the benzol mixtures show very little gain in power at ordinary altitudes over export aviation gasoline. The latter, of course, is a much superior fuel to that sold at filling stations, but there is no reason to believe that it will develop more power than ordinary gasoline in a well-designed engine running under a constant load. Therefore some conclusion may be formed of the relative merits, in regard to power, of benzol blends and ordinary gasoline from these tests comparing such blends with aviation gasoline.

The National Advisory Committee in Report No. 89 compares export aviation gasoline with a blended fuel containing 40 per cent ethyl alcohol, 35 per cent gasoline, 17 per cent benzol, and 8 per cent toluol, ether, etc. The first had a higher heating value of 120,000 B.t.u. per gal.; the second, 106,000 B.t.u. The power developed with the latter fuel was 4 per cent greater than with former. This increment is hardly worthy of note.

The author's general conclusion is that the blended fuels thus far concocted do not develop appreciably greater engine power than gasoline when the engine is in good condition and is adapted to the fuel.

Economy in Fuel Consumption

The operator should not be misled by quotations of efficiency or of pounds or gallons per horsepower-hour. What really concerns him is the number of cents he must pay for the fuel per horsepower-hour or per mile. For example, in the October, 1922, issue of the S.A.E. *Journal* some tests are quoted to show the superiority of benzol-blended gasoline, as follows:

	Gasoline	"Motor Benzol"
Gal. per hp-hr.	0.122	0.109
Thermal efficiency, per cent	18.5	16.9
Cost of fuel per gallon, cents	25	27
Cost of fuel per hp-hr., cents	3.05	2.94

The thermal efficiencies and costs per hp-hr. have been calculated by the author and the resulting figures show a decreased cost of 3 per cent in favor of the motor benzol. This percentage is hardly greater than the experimental error, and inappreciable for practical

Abstract of an address delivered before the Baltimore Section of The American Society of Mechanical Engineers, April 11, 1923.

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purposes. Had the differential of cost between gasoline and the blended fuel been three cents instead of two, the costs per hp-hr. would have been exactly equal. Some of these blended fuels sell at an even greater advance in price than three cents.

The London General Omnibus Company, during the war, kept records of mileage on gasoline versus a blend of 50 per cent benzol and 50 per cent alcohol. These records showed in favor of gasoline in the proportion of a little more than seven to six, and the discrepancy for the blend was more marked in the winter, probably because of the high latent heat of alcohol causing a defective vaporization under low-temperature intake air.

The author has made systematic measurements of mileage per gallon, covering long periods of time, with different blended fuels on the local market, these measurements being made in the operation of a car for personal use. None of these measurements (admittedly inconclusive by themselves) showed an appreciable advantage gained by using blended fuel, *except with a heavily carbonized motor.*

Report No. 47, previously quoted, also states results showing that although the fuel consumption with the alcohol-benzol blend was 12 per cent better than that with gasoline on a weight basis, it was exactly the same with both fuels on a volume basis. The cost of the blended fuel is therefore greater, since the price per gallon is greater.

Operation

Concerning carbon deposits, the carbon from benzol is of softer quality than that from gasoline. The greater volatility of the blended fuel, as shown by its distillation curve, is a factor in its favor in this particular, especially in winter operation. There are no exact comparative data upon the mileage of a motor before carbon must be removed. Laboratory tests in this respect are misleading and road tests inexact.

Benzol is a very smooth-burning fuel and, when mixed with gasoline in as small quantities as 20 per cent, will suppress preignition knocks. This is particularly true of a heavily carbonized motor. This effect may in part be attributed to the higher inflammation point of benzol. It is very generally known that a benzol blend will give a smoother operation, more power, and greater flexibility in a motor carbonized enough to cause preignition with gasoline. It appears also that benzol mixtures exhibit less than straight gasoline the phenomenon of detonation.

Concentrated benzol dissolves shellac, and for this reason is not adaptable to engines with cork-float carburetors. However, commercial benzol-gasoline mixtures may be obtained which contain a comparatively small proportion of benzol and which will not injure the float coating. There has also been some uncertainty concerning the action of these mixtures on tanks and other metallic parts, some testimony indicating that corrosion is caused. It appears, however, that if the blend is properly prepared, this difficulty may be eliminated. This is true also of alcohol mixtures.

As for flexibility, or that vague quality referred to as "pep," within the author's experience there seems to be little preference with a normal motor well designed for a fair grade of gasoline. The same may be said about ability to "start cold" in winter.

It is pertinent, in this comparison, to call attention to the recent finding of the Bureau of Standards, after a wide survey, to the effect that the gasoline now produced in the United States is a better and more volatile fuel than it was two years ago.

Overall Economy

The real criterion of the utility of a fuel is the total cost of operation per mile, including cost of fuel, carbon removal, valve grinding, lubrication, and similar items of upkeep as well as deterioration; always provided the fuel satisfies the requirements of service. All considerations of cost may be swept aside if a fuel is manifestly superior in starting, accelerating, and reliability and, in short, gives the best motor operation. These qualities are as difficult to assess in money value as they are to measure in units of mass, space, or time. The fuel manufacturer is apt to overcapitalize them, and the psychological reaction upon the consumer makes him willing to pay a higher price differential than is commensurate with actual increase of mileage per dollar of operating cost, plus increase of actual serviceability.

As far as the economy item alone is concerned, it has not been conclusively demonstrated that any blended fuel on the market is superior to good gasoline, at prevailing prices. If gasoline increases to 50 cents a gallon, an alcohol-benzol-kerosene mixture, high in alcohol, would have commercial possibilities.

The author's own conclusion is that blended fuel is worth perhaps two cents more per gallon, but a price differential of three to five cents is not justified by the advantages gained.

Relief of Gasoline Shortage

The bugaboo of high-priced fuel due to the exhaustion of petroleum resources has frequently been raised, but as frequently new petroleum fields have been discovered. At present, in the United States, the situation is good. However, there must be a limit, the approach of which will some time be felt. Anything, therefore, which will defer this time must be looked upon with favor. Benzol, alcohol, or any blend for gasoline will make the present supply of petroleum go further. On the other hand, no great effect can be felt from the visible supply of benzol. It has been stated on good authority that if all the bituminous coal annually used in the United States were coked in by-product ovens, the benzol recovered would not amount to more than 25 per cent of the gasoline used in the United States. This seems inconsiderable, but if the economic pressure for good motor fuel results in some reduction of our enormous wastes of the potentialities of coal tar, blended fuels must be looked upon with increased favor. The possibility of petroleum shortage does not alarm the author, but general waste of utilities does. Gasoline may give out, but the possibilities of shale oil, lignite, and even synthetic fuels remain. Come what may, the author is confident that American engineers and chemists will meet the liquid-fuel situation with satisfaction to all concerned.

The Use of Acetone in Composite Engine Fuels

Acetone is a clear, mobile liquid having an agreeable odor and a peppermint-like taste. It is inflammable and burns with a white smokeless flame. Concentrations of acetone vapor with air up to 2.3 per cent will not flash. Above this point there is a slight flash, increasing to and reaching a maximum violence at a concentration of 5.5 per cent of acetone vapor, and settling down to a quiet flame at 10.2 per cent. It has a boiling point of 56.5 deg. cent., or approximately 133 deg. fahr., and is miscible in all proportions with the various fuels used in motor cars. The comparative heating values of acetone and ethyl alcohol are as follows:

	B.t.u. per lb.	B.t.u. per gal.
Acetone	13,476	89,477
Ethyl alcohol	13,028	85,985

Acetone is an excellent engine fuel and in fact approaches the ideal in a number of its properties. Its low boiling point and the resulting high vapor pressure at ordinary temperatures facilitate the starting of the engine. Its homogeneity permits uniform evaporation and distribution, and, therefore, it is conducive to smooth running. Its low freezing point, —94.6 deg. cent (—138.3 deg. fahr.), prevents its solidification at the coldest winter temperatures.

Acetone will not detonate and can be used in an engine with a compression ratio as great as 7 to 1, or with a compression pressure up to 180 lb. per sq. in. It burns with a smokeless flame, does not deposit carbon in the cylinder, and, as far as can be ascertained, has no corrosive action on the cylinder or the various parts of the car with which it comes into contact.

Acetone is an excellent blending agent in reducing detonation. It is miscible in all proportions with all the liquid fuels used in motor cars, and in many instances the addition of a small percentage of acetone combines two immiscible liquids into a homogeneous solution. When it is added in small amounts to heavy hydrocarbon fuels, it minimizes the deposition of carbon and tends to prevent "fuel knocks."

Acetone is the most economical solvent of acetylene and, if saturated with this gas and added to composite engine fuels, will produce a smoother-running mixture, facilitate starting, and permit running on a leaner mixture.—R. F. Remler in the *Journal of the Society of Automotive Engineers*, July, 1923, pp. 23–24.

Endurance-Test Data and Their Interpretation

By K. HEINDLHOFER,[1] and H. SJÖVALL,[2] PHILADELPHIA, PA.

The determination of the endurance of different products is a subject that hitherto has been neglected, yet it is important. It is a general characteristic of products of nature as well as of manufactured products that their life varies within wide limits, and it is thus impossible to judge the life of a certain type of product by a single observation.

The average life determined by repeated endurance tests is a valuable characteristic of comparison as it shows the general magnitude of life, but taken alone it is insufficient to define durability. It must be amended by a second quantity expressing the dispersion or range of variation of the individual lives, which is an indication of reliability. Since the number of available test data is limited its average is approximate, and its precision will depend on the number of data.

The object of the authors in preparing this paper was to develop methods for computing the probable error of the average life of an object or product, depending on the number of repeated tests. This error is a measure of the reliability of the average. The results are presented in the form of a diagram which shows this probable error at a glance. Finally, it is suggested that endurance curves may be employed to determine whether an elimination test will be advantageous in the case of products made in quantity.

THE LIFE of all objects, and especially that of machine parts, varies widely. This is a general characteristic and applies even to objects which apparently are identical, i.e., made in the same factory from the same material, and are used or tested under identical conditions. It is not the authors' intention to investigate the cause of this variability, but rather to represent and to interpret the life or endurance of such objects by figures which may serve as a basis of comparison when the selection or application of machines or machine elements is under consideration.

It is customary to express capacity or performance by figures. We speak of the horsepower of a motor, the watt consumption of a lamp, the gallons-per-minute capacity of a pump, these figures indicating whether the machine in question is suitable for the purpose or worth the price; and it would be equally valuable if we could express how long a gear, a bearing, or a die would stand up under given conditions.

It is not customary to specify life data on machines. This is partly due to the great difficulty and expense of acquiring such data, and partly to the wide discrepancy generally found between results when endurance tests are conducted by two independent parties. In such cases the degree of carefulness exercised in the tests is usually questioned and the testing machines and arrangements are blamed; but granting this, the lack of agreement is mostly due to the variable nature of such data, even if all the conditions are uniform. The discrepancy is due to the inherent variability of endurance in general.

A Method of Interpreting Endurance Data

In spite of this difficulty it is possible to derive endurance figures having a comparative value. This may be achieved by collecting a great number of endurance data on products of the same type and size, tested under identical conditions, and arranging the lives in an ascending sequence, the cumulative number of individuals being the ordinates and the lives the corresponding abscissas. Examples taken from actual observations are shown in Figs. 1, 2, and 3. These graphs are called "cumulative frequency curves."

It is advantageous to standardize the total length of the ordinate, calling it 100 per cent, and subdivide it as shown in Fig. 4. One hundred per cent would then mean the whole number of individual objects tested. It is easy to pick from the diagram the percentage of all the objects tested which have a life longer (or shorter) than a given number of hours, revolutions, or other units. This idea is illustrated in detail in Fig. 4 and Table 1.

In order to be able to obtain these percentages with a sufficient degree of accuracy, an extensive collection of data is required. The number in each interval, say, between 10 and 20 per cent, must be considerable. Such, however, is seldom the case, for the expense of testing often forbids the collection of more than 10 or 20 data. Such a limited number cannot be split up into intervals upon the content of which dependence can be placed, therefore it is preferable to choose a characteristic which is a resultant of all the values available. The average or mean of all the values conforms to this requirement, and at the same time it is readily derived and its meaning simple. In many cases knowledge of the

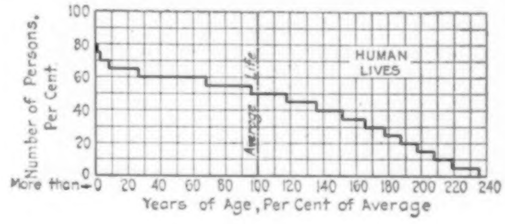

Fig. 1

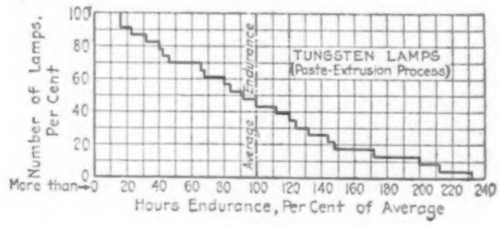

Fig. 2

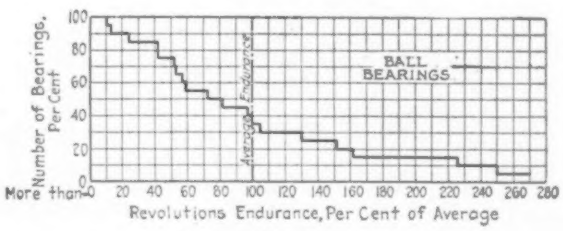

Fig. 3

Figs. 1–3 Examples of Endurance Data Plotted in the Form of Cumulative Frequency Curves

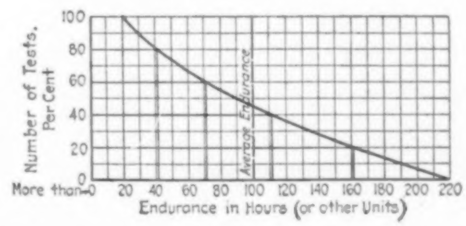

Fig. 4 Representation of Numerous Test Data Obtained Under Identical Test Conditions

TABLE 1 REPRESENTATION OF TEST RESULTS PLOTTED IN FIG.

Percentage of total number of test objects	Endurance in hours, revolutions, or other units, more than
100	20
90	29
80	41
70	55
60	71
50	90
40	111
30	135
20	161
10	189
0	220

average life is sufficient. For example, when a large plant or a city has to be illuminated by incadescent lamps, the cost of replacing the lamps may be determined from the average life of the lamps.

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Presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. All papers are subject to revision.

However, there are other cases where the average alone, while important, is insufficient to enable one to judge of the merit of the product. All the elements of construction from which a high degree of reliability is expected must show as small a fluctuation in endurance as possible. For example, the material of a given part of an airplane should, in addition to a high average, show as little fluctuation as possible. Thus the deviations from the average must not be too great. This requirement would exclude extremely weak specimens.

From this it follows that at least two characteristics, the average life and the variation of lives, are required to define endurance. The difference between the two is best illustrated by the examples presented in Figs. 5 and 6, which show two cumulative curves with identical averages but with different ranges of individual lives. This range or "dispersion" may best be expressed by the

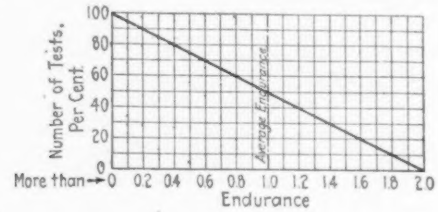

Fig. 5

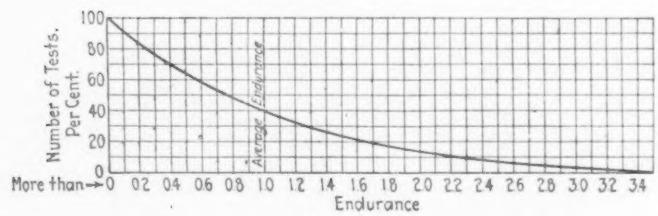

Fig. 6

FIGS. 5 AND 6 ENDURANCE FIGURES OF THE SAME AVERAGE BUT OF DIFFERENT DISPERSIONS

"root-mean-square deviation" of lives from the average, because this value is mainly determined by large deviations. The root-mean-square deviation is obtained by finding the sum of the squares of individual deviations from the mean, dividing this sum by the number of individuals, and extracting the square root.

When introducing the average from a small number of tests which vary between wide limits, a further question arises, namely, how reliable is this value? To answer this question, select, say, 10 data at random from an extensive collection, determine their average, and repeat this process many times. When inspecting the large number of averages thus obtained it will be found that their frequency of occurrence will be greater near the mean of the *whole* collection, and that only a few will be found which deviate greatly from the total mean. Two factors govern their distribution. The

TABLE 2 DATA OF CUMULATIVE FREQUENCY CURVE USED IN EXPERIMENT ON VARIABILITY OF AVERAGE OF ENDURANCE VALUES (SEE FIG. 6)

Total average endurance of an infinite number of tests = 100
Root-mean-square deviation from average = 83.9

Endurance values in 50 intervals				
2	26	60	102	174
4	29	64	108	184
6	32	68	114	195
9	35	72	119	207
11	38	76	125	219
14	42	80	132	234
16	45	84	139	251
18	48	89	146	274
21	52	93	154	301
24	56	98	163	347

first is the number of data (in the present example 10) included in a group, and the second the dispersion or range of the individual values in the original collection. It is obvious that a more homogeneous collection (Fig. 5) yields group averages lying close together, while the opposite is the case with less homogeneous data (Fig. 6).

For the underlying purpose of the work it would be convenient to set limits within which a given percentage of all possible group averages would be located. Other things being equal, the closer the specified limits, the smaller the percentage of group averages within those limits. This statement may also be expressed in another way: the narrower the limits, the smaller the probability of the appearance of average values within them.

The law governing limits when a limited number of data of known dispersion are available, will be illustrated first by an example. The deduction of this law is given later in the paper.

Assume that a not too small number of data have been obtained and tabulated (Table 2), and which, when graphically presented, appear as shown in Fig. 6. Their average value is 100. The root-mean-square deviation from the average is

$$\mu = \sqrt{\frac{98^2 + 96^2 + 94^2 + 91^2 + \ldots}{50}} = 84$$

It is now possible to determine the limits $\pm \Delta$ within which the average value of a limited number of tests on the same product will be located with a probability of, say, 50 per cent. The procedure to determine the limits for any other value of the probability, such as 90 per cent or even 99 per cent, would be similar.

The logarithmic chart forming Fig. 7 renders the computation simple. First the number of test data is located on the lower bounding line of the chart. Let this number be $n = 10$. The intersection of the ordinate of $n = 10$ with the line $P = 0.50$ (i.e., probability = 50 per cent) gives the value $\pm \Delta/\mu = 0.213$. Since the root-mean-square deviation μ is equal to 84, $\pm \Delta = 0.213 \times 84 = 18$. This means that the probability is 50 per cent that the average life of 10 tests is within the limits of 100 ± 18. The probable error is thus ± 18. Fig. 9 shows these limits.

A second example is shown in Fig. 8, where $n = 10$ and $\mu = 58$.

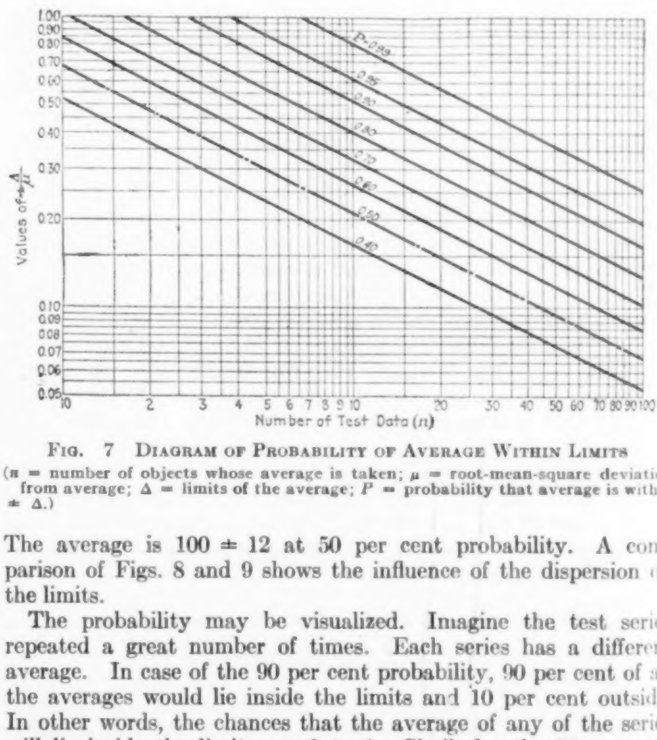

FIG. 7 DIAGRAM OF PROBABILITY OF AVERAGE WITHIN LIMITS

(n = number of objects whose average is taken; μ = root-mean-square deviation from average; Δ = limits of the average; P = probability that average is within $\pm \Delta$.)

The average is 100 ± 12 at 50 per cent probability. A comparison of Figs. 8 and 9 shows the influence of the dispersion on the limits.

The probability may be visualized. Imagine the test series repeated a great number of times. Each series has a different average. In case of the 90 per cent probability, 90 per cent of all the averages would lie inside the limits and 10 per cent outside. In other words, the chances that the average of any of the series will lie inside the limits are 9 to 1. Similarly, the 50 per cent probability represents equal chances, for which reason the magnitude between the limits is called the probable error.

VERIFICATION OF THE PROPOSED METHOD

The procedure for determining the probable error of the average, and the more general case of setting limits which include the average at any desired probability, having been described, it remains to be shown how the values used in plotting Fig. 7 were obtained.

From the theory of least squares it is known that the probability P of an error $\pm \Delta$ of the average value of n observations may be expressed by the formula

$$P_{\pm\Delta} = \frac{2}{\sqrt{\pi}} \int_0^{\frac{\sqrt{n}}{\sqrt{2}}\frac{\Delta}{\mu}} e^{-t^2} dt \ldots\ldots\ldots\ldots\ldots [1]$$

where μ is the root-mean-square deviation. This formula has been derived under the assumption that the errors of individual observations occur at random, i.e., that they follow Gauss's law of frequency of error.

Fig. 7 is based on Formula [1] and is constructed as follows: The number of tests n and Δ/μ are arbitrarily assumed, thus determining the upper limit of the integral. The integral may then be evaluated by tables found in handbooks. The corresponding values of Δ/μ, n, and P may then be plotted, preferably on logarithmic paper.

It remains to be shown, however, that Formula [1] is applicable with sufficient accuracy to cumulative frequency curves (Figs. 1, 2, 3, and 4) which do not necessarily follow Gauss's law.

TABLE 3 EXPERIMENT ON THE VARIABILITY OF THE AVERAGE VALUE OF A LIMITED NUMBER OF DRAWINGS

(Each score is the average of 10 drawings from the numbers given in Table 2)

Percentage of ideal average	Distribution of 250 scores							
0 to 10	0							
10 to 20	0							
20 to 30	0							
30 to 40	1							
40 to 50	1							
50 to 60	11111	11						
60 to 70	11111	11111	11111	1				
70 to 80	11111	11111	11111	11111	11111	1111		
80 to 90	11111	11111	11111	11111	11111	11111	1111	
90 to 100	11111	11111	11111	11111	11111	11111	111	
100 to 110	11111	11111	11111	11111	11111	11111	11111	11
110 to 120	11111	11111	11111	11111	11111	11111	11	
120 to 130	11111	11111	11111	11111	11111	1		
130 to 140	11111	11111	11111	1				
140 to 150	11111	111						
150 to 160	11111							
160 to 170	1111							
170 to 180	1							
180 to 190	0							
190 to 200	0							

A general proof based on the symbolic method appears to be difficult because the shapes of the cumulative curves are arbitrary. For the purpose in hand it was considered sufficient to apply Formula [1] to two cumulative curves which represent typical conditions such as obtain in practice. In order to broaden the limits of the proof, extreme conditions have been chosen.

In the first example a cumulative curve is assumed the asymmetry of which with respect to the average is pronounced (Fig. 6 and Table 2). The endurance values which define this curve were derived from actual test series. In the second example the curve is a straight line (Fig. 5). This symmetrical distribution corresponds to the so-called problem of De Moivre.[1]

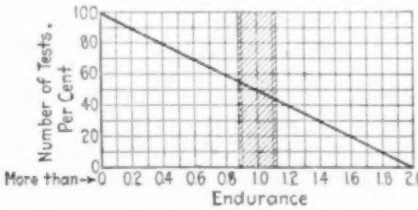

FIG. 8

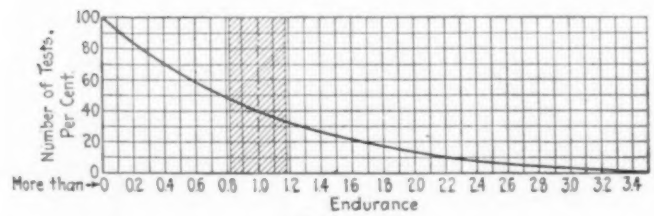

FIG. 9

FIGS. 8 AND 9 LIMITS INCLUDING 50 PER CENT OF ALL POSSIBLE AVERAGES OF 10 VALUES PICKED AT RANDOM FROM THE CUMULATIVE FREQUENCY CURVES OF FIGS. 5 AND 6

The proof consists in computing the probabilities by a method the correctness of which cannot be questioned. These values are then to be compared with those derived by using Formula [1], when the comparison will bear out any possible discrepancy. While for the first example an experimental method was used, the second was calculated according to a rigorously correct formula.

The experimental procedure was as follows: The figures given in Table 2 were printed on small wooden disks and collected in an urn. A disk was drawn therefrom and its number recorded. This disk was then returned and the contents of the urn were thoroughly and systematically mixed to insure a random appearance of the disks. The procedure was then repeated a great number of times (2500). Figures thus obtained were arranged in groups of $n = 10$ in the sequence they appeared. Each group was averaged and the results arranged as in Table 3. The frequency of average within a certain interval may be found from this tabulation. The probabilities thus obtained and the corresponding values calculated by using Formula [1] are compiled in Table 4.

TABLE 4 VERIFICATION OF FORMULA [1] FOR 10 DRAWINGS

(a) STRAIGHT LINE, FIG. 5 (Root mean square = 0.577; average = 1.000)

Δ = Limit on either side of the average	Probability: Calculated according to Formula [1] or Fig.7	Probability: Mathematically correct values
±0.1	0.416	0.412
0.2	0.727	0.722
0.3	0.900	0.900
0.4	0.967	0.973
0.5	0.994	0.995
0.6	0.999	0.999

(b) CUMULATIVE FREQUENCY CURVE, FIG. 6 (Root mean sq. = 0.893; avg. = 1.000)

Δ = Limit on either side of the average	Probability: Calculated according to Formula [1] or Fig. 7	Probability: Experimentally determined from 250 scores at 10 drawings. (See Table 3)
±0.1	0.294	0.280
0.2	0.549	0.544
0.3	0.742	0.764
0.4	0.868	0.892
0.5	0.940	0.952
0.6	0.976	0.976
0.7	0.992	0.996
0.8	0.997	1.000
0.9	0.999	1.000

In case of the straight-line distribution (Fig. 5) the probabilities for given limits and 10 tests per group were calculated from De Moivre's formula. These figures are also entered in Table 4 with corresponding values calculated from Formula [1].

The agreement between the corresponding figures is satisfactory, justifying the approximation involved in the use of Formula [1], which serves to determine the limits of averages such as those derived from endurance-test data. The agreement would be still better for $n>10$, while for $n<10$ the accuracy would necessarily be lower.

IMPROVING THE ENDURANCE OF QUANTITY PRODUCTS BY ELIMINATION TESTS

In addition to their function of gaging quality and reliability, cumulative endurance curves may be applied in a constructive manner. Imagine a quantity product having a cumulative frequency curve like that of Fig. 1. It is evident that this product would be considerably improved by subjecting it to an endurance test resembling service conditions for about one-tenth of the time of the average life before the product left the factory. By this procedure 35 per cent would be eliminated, improving the average of the remainder by approximately 50 per cent.

An improvement is not always effected by running all articles through such a test. For example, the products dealt with in Figs. 2 and 3 would lose in value by this process.

A judgment as to whether an elimination test will be advantageous or not can only be based on a careful study of cumulative endurance data.

CONCLUSIONS

There are three characteristic figures which define the endurance quality of a product:

(1) The average life, which shows the general magnitude of life

(2) The dispersion or root mean square, which expresses reliability of the *product* itself

(3) The probable error of the average. This indicates the reliability of the *average;* in other words, it shows whether or not the test has been repeated a sufficient number of times.

Discussion

FOLLOWING its presentation Mr. Heindlhofer, in reply to questions put to him, elaborated several of the statements made in the paper. If, for example, he said, a crankshaft were put in an automobile engine and run under test it would break

(*Continued on page 625*)

[1] E. Czuber, Wahrscheinlichkeitsrechnung, 3d ed., pp. 63–66, Leipsic; B. G. Teubner.

Bending Stresses in Curved Tubes of Rectangular Cross-Section[1]

By S. TIMOSHENKO,[2] EAST PITTSBURGH, PA.

In this paper the author analyzes the stresses in bent tubes of rectangular cross-section and shows that in the case of thin tubes the distortion due to bending results in greater flexibility and less strength than given by the usual formulas. In an appendix to the complete paper an approximate solution of the problem is obtained by a consideration of the potential energy of deformation.

THE bending of curved tubes is accompanied by a distortion of the cross-section. As a result of this distortion thin tubes are more flexible and have less strength than given by the usual formulas. In one example of a Fairbairn crane, considered later, the maximum stress is 67 per cent greater than the value given by the ordinary formula for the bending of curved bars.

This paper will consider the case of the bending of a tube under the action of moments M only. Referring to Fig. 1, if the dimension a of the cross-section is small in comparison with the radius of curvature R of the tube, the maximum stress and the increase of the angle α are usually calculated by the formulas

$$p_{max} = \frac{aM}{2I} \qquad [1]$$

$$\Delta\alpha = \alpha\frac{MR}{EI} \qquad [2]$$

where E denotes the modulus of elasticity and I the moment of inertia of the cross-section about the neutral axis.

In the case of a solid cross-section these formulas are sufficiently accurate, but in the case of a tube the problem is more complex. The forces of tension acting on any element ss_1 (Fig. 1) and the forces of compression acting on any element rr_1 give resultants whose direction is toward the neutral axis. These forces produce the distortion of the cross-section shown in Fig. 1 (*b*).

Assuming that the cross-sections of the tube remain plane on bending, the conclusion follows that the elongation e of any element ss_1 will depend not only on the increase $\Delta\alpha$ of the angle α, but also on the radial displacement w due to the distortion of the cross-section.

Let $s's_1'$ represent the position of the element ss_1 after deformation [Fig. 1 (*a*)]. It is seen that the extension ls_1' of the element can be represented by

$$ls_1' = ks_1' - kl$$

The first term on the right-hand side of this equation, due to rotation of the cross-section s_1r_1 about the neutral axis X, is equal to $\frac{\Delta\alpha a}{2}$; w is assumed to be small in comparison with a. The second term, due to radial displacement w, is equal to $w\alpha$. Substituting this value in the equation and dividing it by $R\alpha$, the initial length of the element ss_1 (a assumed to be small in comparison with R), the following expression is obtained for the longitudinal strain of the element ss_1:

$$e = \frac{\Delta\alpha a}{2R\alpha} - \frac{w}{R} \qquad [3]$$

Formula [3] may also be used in calculating the compression of any element rr_1. It is seen that as a result of the distortion of the cross-section, the stresses at the middle of the plates mn and qt become less than those given by Formula [1]. This decrease of stresses in the central portions of mn and qt will necessarily be associated with an increase of stresses in other parts of the cross-section.

The true values of the maximum stress and of the increase of the angle α may be obtained by using Formulas [1] and [2], if for I there be substituted a smaller quantity

$$I_1 = \beta I \qquad [4]$$

where the coefficient β, less than unity, is to be calculated by the following formula:

$$\beta = 1 - 2\Lambda \times \frac{12(1-\sigma^2)\left[2 + \frac{1}{2}\frac{b}{a}\left(\frac{h_2}{h_1}\right)^3\right]^2}{\pi^2\left(1+\frac{i_2}{i_1}\right)\left[\pi^4 + 4\pi^2\frac{b^2}{a^2}\left(\frac{h_2}{h_1}\right)^6 + \frac{40}{3}\pi^2\frac{b}{a}\left(\frac{h_2}{h_1}\right)^3\right] + 12\Lambda(1-\sigma^2)\pi^2\left(1+\frac{i_2}{i_1}\right)\left[1 + \frac{3}{4\pi^2}\frac{b^2}{a^2}\left(\frac{h_2}{h_1}\right)^6 + \frac{16}{3\pi^2}\frac{b}{a}\left(\frac{h_2}{h_1}\right)^3\right]} \qquad [5]$$

where

h_1 = thickness of horizontal plates mn and qt

h_2 = thickness of vertical plates mq and nt

i_1 = moment of inertia about neutral axis of the horizontal plates

i_2 = moment of inertia about neutral axis of the vertical plates

σ = Poisson's ratio of the material (in these calculations $\sigma = 0.3$)

and
$$\Lambda = \frac{b^4}{R^2h_1^2} \qquad [6]$$

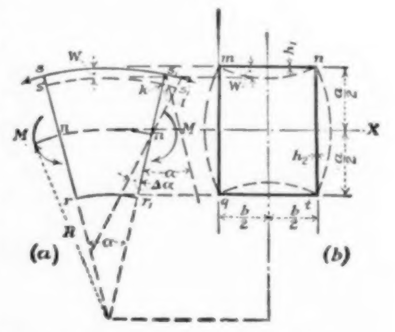

FIG. 1 SECTION OF BENT TUBE OF RECTANGULAR CROSS-SECTION

In the case of a tube of square cross-section and of a constant thickness h,

$$a = b;\ h_1 = h_2 = h$$

$$\frac{i_2}{i_1} = \frac{ha^3}{6} : \frac{ha^3}{2} = \frac{1}{3}$$

and from Formula [5],

$$\beta = \frac{49.18 + 1.332\Lambda}{49.18 + 3.232\Lambda} \qquad [7]$$

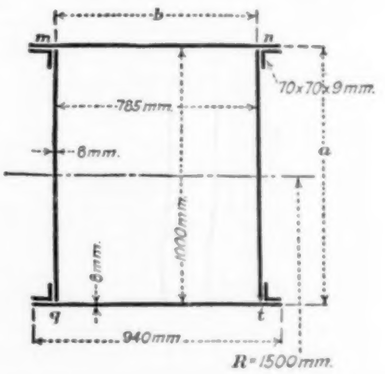

FIG. 2 CROSS-SECTION OF FAIRBAIRN CRANE BOX GIRDER

The effect of distortion of cross-section depends on the magnitude of the quantity Λ. If Λ is small, i.e., in the case where the radius R and the thickness h are large, the coefficient β will be nearly unity and Formulas [1] and [2] will give sufficiently accurate results. Taking another extreme case and putting $\Lambda = \infty$ in [7], $\beta = 0.412$. In this case the maximum stresses and the flexibility of the tube are about 2.5 times greater than the values given by Formulas [1] and [2].

As an example, take $\frac{R}{a} = 10$; $\frac{a}{h} = 50$. Then, from [6], $\Lambda = 25$, which, substituted in [7], gives $\beta = 0.513$. The maximum stresses in this case will be about twice as great as given by Formulas [1] and [2].

(*Continued on page 612*)

[1] The case of tubes of circular cross-section has been considered by Prof. Th. Karman. See *Zeit. Ver. Deutsch. Ing.*, 1911, p. 1889.

[2] Research Dept., Westinghouse Elec. Mfg. Co.

Presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged by omission of appendix. All papers are subject to revision.

The Strength of Bolt Threads as Affected by Inaccurate Machining[1]

Results of Experiments Conducted at the Bureau of Standards to Determine the Effect of Variations in the Pitch-Diameter Clearance and the Face Angle of the Nut on the Tensile Strength—Effect of Materials Used

By GEORGE M. DEMING,[2] SEATTLE, WASH.

THE National Screw Thread Commission, created by Act of Congress (H. R. 10852) approved July 18, 1918, for the purpose of ascertaining and establishing standards for screw threads for the use of the various branches of the Federal Government and for the use of manufacturers, have recommended a system of threads in their Progress Report dated January 4, 1921.[3] This report describes the threads approved by the commission and gives information, data, and specifications pertaining to their manufacture.

The strength of screw threads did not receive particular attention by the Commission, but their Research Committee[4] proposed a preliminary experimental program to determine the effect of extreme inaccuracies in machining which sometimes occur in commercial work. At its request the Bureau of Standards undertook the experimental work, using the test specimens supplied by the Committee.

Description of the Test Specimens

There are many variations both in the material and the dimensions of commercial bolts and nuts. Many of these, however, have little influence upon their strength or usefulness.

Differences in the fit of the nut on the bolt are obtained by varying the pitch-diameter clearance between the bolt and nut.

Four classes of screw-thread fits, with subdivisions, were established by the Commission. These are

- Class I, loose fit
- Class II, medium fit: A, regular; B, special
- Class III, close fit
- Class IV, wrench fit: A for light sections, B for heavy sections.

The strength of the threads under axial loading should increase from Class I, loose fit, to Class IV, wrench fit. In order to determine the effect on strength due to differences in fit the specimens marked 4-A and 4-B were tested. The threads on the internal member were all of the same size and the variations in clearance were obtained by tapping the nuts oversize. This method differs from that adopted by the Screw Thread Commission in their report. They recommend that differences in fit be obtained by variations in the pitch diameter of the screw. The dimensions and other data for these specimens are given in Table 1. It will be noted that the dimensions of these threads, in most cases, do not come within the limits established by the Commission, but it is believed that the effect of the measured pitch-diameter clearance on the strength does not depend upon close adherence to these standards.

The strength of the thread also depends upon the proper bearing of the face of the nut. If the face is not perpendicular to the axis of the screw, bending of the screw will occur when load is applied and the strength of the thread will be decreased.

To determine the effect of this eccentric loading, the specimens marked 5-A, 5-B, and 5-C were tested. The dimensions and other data for these specimens are given in Table 2.

The material for each group of specimens was the steel often used in commercial work with those threads. No data are available regarding the physical properties of these materials. All the screws were very carefully threaded with a die, the same die being used for all similar specimens. All nuts were very carefully tapped, using the same tap for all to have the same fit. Three screws and nuts for each fit were prepared and one of each measured at the Bureau of Standards.

Method of Testing

All the bolts were loaded in tension, using a Riehlé testing machine having a capacity of 50,000 lb. The nut was held by the stationary head of the machine and the load applied to the bolt by the moving head. A dial micrometer attached to the nut was used to measure the movement of the screw with respect to the nut. This instrument was graduated to 0.0001 in., and tenths of a division could be readily estimated.

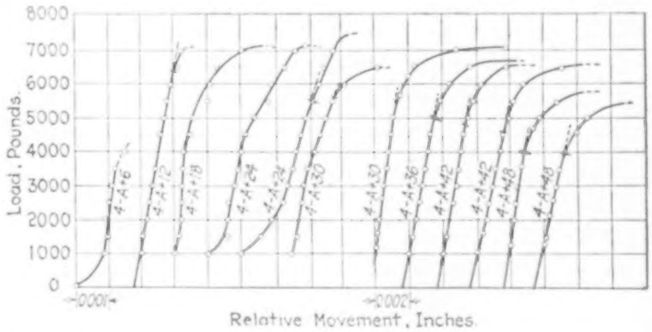

FIG. 1 LOAD GRAPHS FOR SPECIMENS 4-A, NATIONAL COARSE-THREAD SERIES—CLEARANCE

(Scale for relative movement for Specimens Nos. 4-A+36 to 4-A+48 is 0.002 in.)

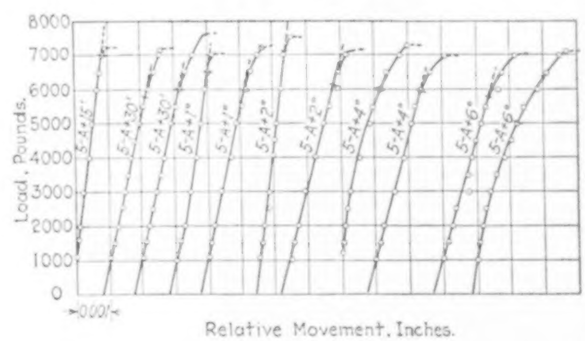

FIG. 2 LOAD GRAPHS FOR SPECIMENS 5-A, NATIONAL COARSE-THREAD SERIES—FACE ANGLE

The movement was read for load increments of 500 lb. until the yield point was reached. Load graphs were then drawn, from which the proportional limit was determined. Figs. 1 and 2 give these graphs for two series of tests.

The yield point was found by the "drop of the beam" of the testing machine and by the very rapid increase in the movement shown by the dial micrometer. The yield point was well defined in all the specimens.

The ultimate strength, in most cases, was not determined as the failure of the thread was studied by cutting away both nut and screw to an axial plane. Characteristic failures are shown in Fig. 3.

Results of the Tests

The results of the tests are given in Tables 1 and 2 and in part in the load graphs Figs. 1 and 2.

Inspection of the load graphs shows, as might be expected, that

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[1] Published by permission of the Director of the Bureau of Standards of the U. S. Department of Commerce.

[2] Instructor, Pacific Telephone & Telegraph Co.'s Plant School.

[3] No. 42, Miscellaneous Publications of the Bureau of Standards.

[4] The members of the Research Committee were E. H. Ehrman, Chairman, Maj. O. B. Zimmerman, and Commander S. M. Robinson.

TABLE 1 STRENGTH OF BOLT THREADS UNDER AXIAL LOADING

SPECIMENS 4-A—NATIONAL COARSE-THREAD SERIES

(Screws and nuts, open-hearth cold-rolled steel; lead error of screw, +0.0026 in. in 10 threads)

Specimen No.	Tap Used for Nuts (3/8 in. 16 thd. U.S. Std.) Size, pitch diam. plus	Make	Measured Dimensions — Nut — Minor diam., in.	Nut — Pitch diam., in.	Screw — Major diam., in.	Screw — Pitch diam., in.	Pitch-diameter clearance, in.	Tensile Test — Proportional limit (av'g), lb.	Tensile Test — Yield point (av'g), lb.
4-A + 0	......	Regular	0.319	0.351	0.373	0.336	0.015	..	7090
4-A + 6	0.006 in.	Special	0.318–0.320	0.359–0.361	0.373	0.336	0.023–0.025	3500	7100
4-A + 12	0.012 in.	Special	0.322	0.358	0.373	0.336	0.022	6400	7150
4-A + 18	0.018 in.	Special	0.325	0.361	0.373	0.336	0.025	4000	7270
4-A + 24[1]	0.024 in.	Special	0.334	0.361	0.373	0.336	0.025	5000	7340
4-A + 30	0.030 in.	Special	...	0.364	0.373	0.336	0.028	5600	6645
4-A + 36[2]	0.036 in.	Special	...	0.372	0.373	0.336	0.036	5050	6930
4-A + 42[3]	0.042 in.	Special	...	0.377	0.373	0.336	0.041	4700	6645
4-A + 48[4]	0.048 in.	Special	...	0.385	0.373	0.336	0.049	4000	5655
Basic Dimensions, Screw Thread Com.....			0.2938	0.3344	0.375	0.3344			

SPECIMENS 4-B—NATIONAL FINE-THREAD SERIES

(Screws, 3½ per cent nickel steel, heat treated; nuts, open-hearth cold-rolled steel; lead error of screw, −0.0015 in. in 15 threads)

Specimen No.	(3/8 in. 24 thd. S.A.E. Std.) Size, pitch diam. plus	Make	Nut — Minor diam., in.	Nut — Pitch diam., in.	Screw — Major diam., in.	Screw — Pitch diam., in.	Pitch-diameter clearance, in.	Proportional limit (av'g), lb.	Yield point (av'g), lb.
4-B + 0	......	Regular	0.339	0.366	0.376–0.380	0.351–0.352	0.015	8000	10745
4-B + 4	0.004 in.	Special	0.343	0.373	0.376–0.380	0.351–0.352	0.022	7000	10796
4-B + 8	0.008 in.	Special	0.344–0.350	0.375	0.376–0.380	0.351–0.352	0.024	7200	10100
4-B + 12[5]	0.012 in.	Speical	0.345	0.376	0.376–0.380	0.351–0.352	0.025	6550	9273
4-B + 20[6]	0.020 in.	Special	0.342	0.377	0.376–0.380	0.351–0.352	0.026	6233	8000
Basic Dimensions, Screw Thread Com.....			0.3209	0.3479	0.3750	0.3479			

[1] In one test (yield point 7500 lb.) bolt broke. [2] In one test (y. p. 7100 lb.) bolt broke near head. [3] In one test (y. p. 6600 lb.) nut yielded. [4] In one test (y. p. 5850 lb.) nut yielded. [5] In one test (y. p. 9500 lb.) thread stripped in nut. [6] In two tests (y. p. 8000 lb.) thread stripped in nut.

TABLE 2 STRENGTH OF BOLT THREADS UNDER ECCENTRIC LOADING

SPECIMENS 5-A—NATIONAL COARSE-THREAD SERIES

(Screws and nuts, open-hearth cold-rolled steel; lead error of screw, +0.0017 in. in 10 threads; all nuts tapped with regular 3/8-in. 16-thread U. S. Standard tap)

Specimen No.	Angle of face of nut, deg.	Measured Dimensions — Nut — Minor diam., in.	Nut — Pitch diam., in.	Screw — Major diam., in.	Screw — Pitch diam., in.	Pitch-diameter clearance, in.	Tensile Test — Proportional limit (av'g), lb.	Tensile Test — Yield point (av'g), lb.
5-A + 15′	0.25	0.304	0.357	0.375	0.337	0.020	7000	7235
5-A + 30′	0.50	0.304	0.357	0.375	0.337	0.020	5900	7410
5-A + 1°	1.00	0.304	0.357	0.375	0.337	0.020	6250	7100
[1]5-A + 2°	2.00	0.304	0.357	0.375	0.337	0.020	6600	7345
5-A + 4°	4.00	0.304	0.357	0.375	0.337	0.020	6000	7150
5-A + 6°	6.00	0.305	0.356	0.375	0.337	0.019	5400	7065
Basic Dimensions, Scr. Thd. Com.....		0.2938	0.3344	0.375	0.3344			

SPECIMENS 5-B—NATIONAL FINE-THREAD SERIES

(Screws, 3½ per cent nickel steel; nuts, open-hearth cold-rolled steel; lead error of screw, +0.0025 in. in 15 threads; all nuts tapped with regular 3/8-in. 24-thread S.A.E. Standard tap)

Specimen No.	Angle of face of nut, deg.	Nut — Minor diam., in.	Nut — Pitch diam., in.	Screw — Major diam., in.	Screw — Pitch diam., in.	Pitch-diameter clearance, in.	Proportional limit (av'g), lb.	Yield point (av'g), lb.
5-B + 15′	0.25	0.327	0.355	0.372	0.349–0.350	0.005	8000	9650
5-B + 30′	0.50	0.327	0.355	0.372	0.349–0.350	0.005	7250	9280
[1]5-B + 1°	1.00	0.327	0.355	0.372	0.349–0.350	0.005	7600	9155
[2]5-B + 2°	2.00	0.327	0.355	0.372	0.349–0.350	0.005	5950	9340
5-B + 4°	4.00	0.327	0.355	0.372	0.349–0.350	0.005	7000	9555
5-B + 6°	6.00	0.327	0.355	0.372	0.349–0.350	0.005	7100	9770
Basic Dimensions, Scr. Thd. Com.....		0.3209	0.3479	0.375	0.3479			

SPECIMENS 5-C—NATIONAL FINE-THREAD SERIES

(Screws and nuts, 3½ per cent nickel steel, heat-treated; lead error, +0.0024 in. in 15 threads; all nuts tapped with regular 3/8-in. 24-thread S.A.E. Standard tap)

Specimen No.	Angle of face of nut, deg.	Nut — Minor diam., in.	Nut — Pitch diam., in.	Screw — Major diam., in.	Screw — Pitch diam., in.	Pitch-diameter clearance, in.	Proportional limit (av'g), lb.	Yield point (av'g), lb.
[2]5-C + 15′	0.25	0.329	0.358	0.371–0.373	0.347–0.349	0.010	7000	9465
[2]5-C + 30′	0.50	0.329	0.358	0.371–0.373	0.347–0.349	0.010	7150	9510
5-C + 1°	1.00	0.329	0.358	0.371–0.373	0.347–0.349	0.010	7150	9510
[2]5-C + 2°	2.00	0.329	0.358	0.371–0.373	0.347–0.349	0.010	7600	9515
[3]5-C + 4°	4.00	0.329	0.358	0.371–0.373	0.347–0.349	0.010	8550	9750
[1]5-C + 6°	6.00	0.325	0.360	0.371–0.373	0.347–0.349	0.012	8000	9595
Basic Dimensions, Scr. Thd. Com.....		0.3209	0.3479	0.375	0.3479			

[1] In one of the two tests bolt failed in thread at face of nut. [2] In both of the two tests bolt failed in thread at face of nut. [3] In one test (yield point 9480 lb.) bolt failed in thread at face of nut; in the other, nut yielded.

the curves are not as regular as those obtained from tension tests of steel specimens. The unusual irregularity of the curves for specimens 4-A+6 to 4-A+30, Fig. 1, may possibly be due to lack of experience on the part of the men making the tests. The slope of the curve is not considered significant for this work nor the fact that some of the curves are concave and some convex toward the axis of loads.

The proportional limit was taken as the load at which the curve departed from the straight line and was in nearly all cases very well defined. The decrease in the proportional limit and in the yield point as the clearance or the angle of the face of the nut are increased is clearly shown. It is probable that the yield point is, for practical purposes, the ultimate strength of the threads. This is shown by the fact that the curves are nearly horizontal at the yield point, and the sections, Fig. 3, show that little additional load could be sustained by any of the specimens except perhaps 5-C+6°. The proportional limit may be taken as the elastic limit of the screw with nut. If it is not exceeded, any relative displacement which persists after removal of the load is probably due to local crushing of the thread surfaces in contact rather than to permanent set of the material as a whole.

The movement which occurs before the yield point is reached can be estimated from the curves. For example, the movement for the clearance specimens shown in Fig. 1 for Series 4-A is about three times that at the proportional limit, while the specimens of Series 4-B moved nearly twice as far before failure. This may be due either to the material or to the size of the threads, but it suggests that fine-thread screws of heat-treated nickel steel in combination with open-hearth cold-rolled steel nuts resist abuse better than coarse-thread bolts and nuts of open-hearth cold-rolled steel. This is a matter of particular importance for bolts of small diameter, which are frequently overstrained when assembling by the use of a long wrench applied with little judgment.

The fine-thread screws are stronger than those having a coarse thread as is shown by Figs. 4 and 5, which also show the effect of clearance on the strength. The strength of the coarse threads, Fig. 4, is decreased but little as the clearance is increased. It should be noted that the depth of the thread is 0.0406 in., so that a clearance of 0.050 in. leaves only 0.0156 in. or 38 per cent of the threads engaged. In spite of this both the proportional limit and the yield point were only decreased about 25 per cent. This clearance is much greater than the 0.0144 in. for loose fits recommended as the maximum by the Screw Thread Commission, and is greater than should occur in practice.

No tests were made upon specimens having small clearances, but the curves in Fig. 4 give no indication that appreciably higher strengths would have been obtained. As, however, only 81 per cent of the thread surfaces are in contact, greater strength would be expected, particularly for the close and wrench fits. Experimental work could well be undertaken to supply information on this point.

The fine-thread nickel-steel screws show a marked decrease in strength with increase in clearance, as shown by Fig. 5. In this case there is reason to believe that screws having less than 0.015 in. clearance would show higher strengths. The smallest clearance tested is, for these specimens as well as for those having coarse threads, much greater than the 0.0105 in. recommended by the Commission. As the depth of thread is 0.0271 in., only 72 per cent of the thread surfaces are in contact if the clearance is 0.015 in., while the Commission recommends at least 91.5 per cent. The strength, especially the yield point, decreased very rapidly with an increase in clearance, this decrease for an increase in clearance from 0.015 to 0.026 (52 per cent of the thread surfaces in contact) was about 25 per cent for both the yield point and the proportional limit.

The difference in the behavior of the coarse- and the fine-thread specimens is not easily explained. If made of the same material and with the clearance in both cases proportional to the depth of the thread, it is probable that the strengths would be the same. Screws of nickel steel, heat treated, should be stronger than those of cold-rolled steel. The area to be sheared at the base of the thread, if failure occurred in that way, is much larger for the nut than for the screw, which would justify nickel-steel screws. Fig. 3 shows, however, that failure occurred by shearing or bending the thread in the nut. As the decrease in strength in each case was about 25 per cent for the greatest clearance tested, there is no very noticeable difference in this respect although the fine-thread series decreased most rapidly.

The effect of varying the angle of the face of the nut is shown in Fig. 6. The angles are in all cases so small that the screw is

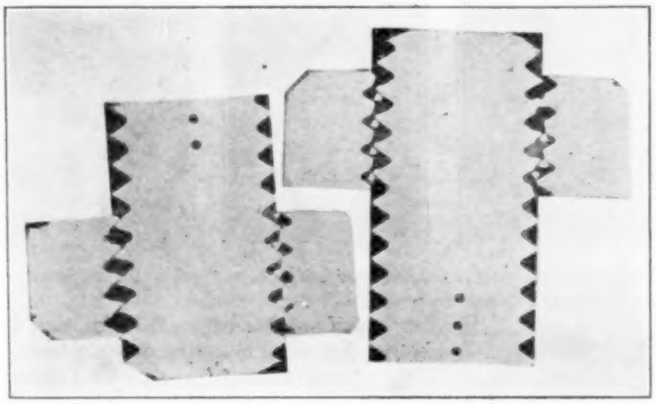
apparently bent until the nut bears over the entire face without decreasing its strength. A slight decrease, as shown at 5-A, might be expected, but increases are shown at 5-B and 5-C. It should be remembered that in service in tightening the nut there is a reversal of stress in the bolt which may reduce the strength much below that found for these tests.

The amount of movement after the proportional limit is reached is the lowest for the screw and nut of open-hearth cold-rolled steel, as in the clearance tests, and the greatest for the nickel-steel screw in the cold-rolled-steel nut. The screw and nut of nickel steel appear to have a movement between these two.

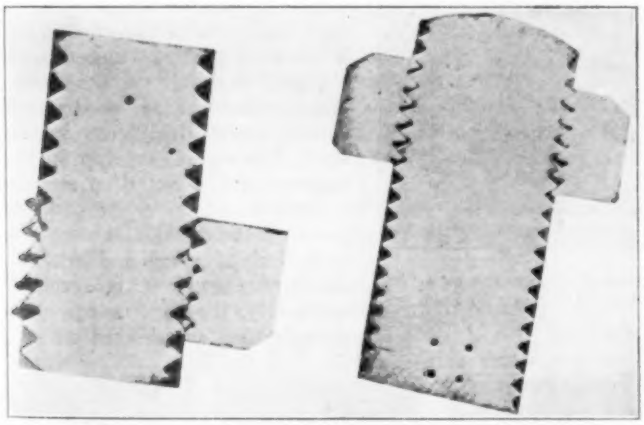
Conclusions

1 The axial movement of a screw in its nut is approximately proportional to the load until a load is reached after which the movement increases rapidly.

2 The yield point shown by "drop of beam" or the rapid increase



No. 4-A + 36 No. 4-A + 48



No. 4-A + 36 No. 5-C + 6°

Fig. 3 Sections Through Screws and Nuts after Tensile Test, Showing Failure of the Threads

in the relative movement of the screw and nut is practically the ultimate strength of the threads.

Effect of Variation in Pitch-Diameter Clearance:

3 As the clearance increases, the rate of movement between screw and nut increases.

4 As the clearance increases the proportional limit and yield point decrease, but the effect is not very great for tolerances and allowances recommended by the Screw Thread Commission.

Effect of Variation in the Face Angle of the Nut:

5 As the face angle of the nut with a plane perpendicular to the axis of the thread increases, the rate of axial movement of the screw in the nut increases.

6 As the face angle of the nut increases the proportional limit and yield point are practically constant for angles up to 6 deg.

Effect of Material upon the Tensile Strength:

7 Apparently the strength is increased if, instead of making the screw and nut of open-hearth cold-rolled steel, the screw is made from heat-treated nickel steel. It is possible that the increase from 7000 lb. to nearly 10,000 lb. may have been due to the use of coarse threads in the first and of fine threads in the second case.

8 For heat-treated $3^1/_2$ per cent nickel-steel screws, open-hearth cold-rolled steel nuts gave as great strength as nuts of the same material as the screws.

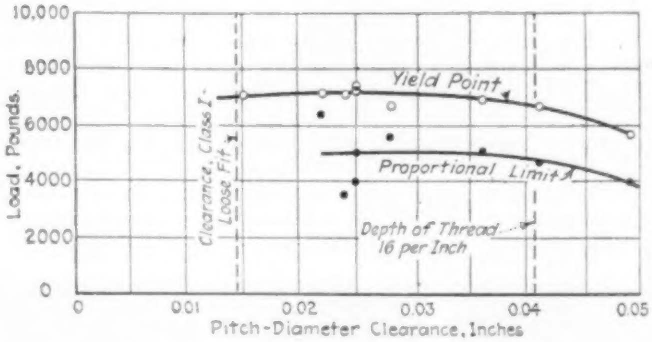


Fig. 4 Effect of Clearance on Strength of Coarse Threads, Specimens 4-A

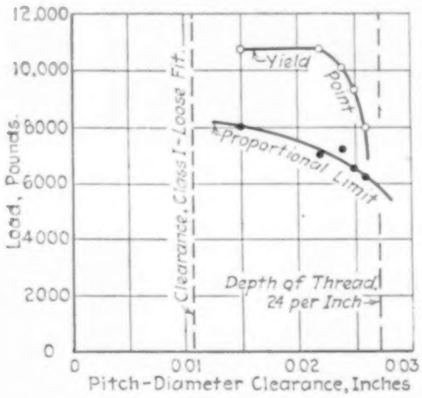


Fig. 5 Effect of Clearance on Strength of Fine Threads, Specimens 4-B

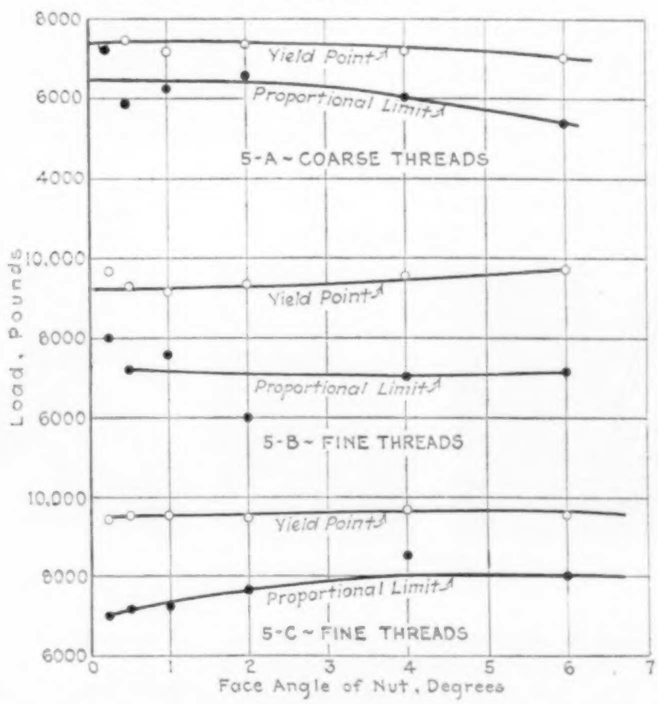


Fig. 6 Effect of Face Angle of Nut on Strength of Threads

9 The nickel-steel specimens, even when the nut was of open-hearth cold-rolled steel, showed more movement after the proportional limit was reached than the specimen having both screw and nut of open-hearth cold-rolled steel. This may prove to be an advantage if the threads are abused as by overstraining.

Chip Formation by Milling Cutters

By C. F. Roby,[1] Cincinnati, Ohio

To understand the phenomena occurring during the failure of any metal-cutting tool, it is necessary to know the mode of formation of the chip. The object of the investigation undertaken by the author and described below was to determine by observation the successive steps in the formation of a milling-machine chip. The cutting action of a turning tool has already been explained by the late Dr. F. W. Taylor and Prof. John T. Nicolson.

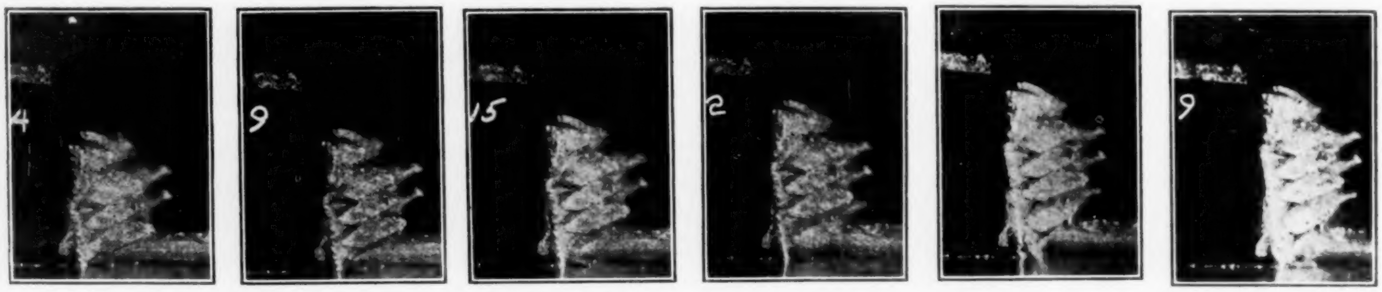


Fig. 1 Stages in the Formation of a Chip by a Tool Having a Rake Angle of 20 Deg.
(Depth of cut, 0.080 in.; angle of shear, 24 deg.)

The machine employed for the test was a No. 3 Brown & Sharpe milling machine. By a system of indirect belt drive from an electric motor the spindle was run at the low speed of 0.2 r.p.m., giving a cutting speed of 1.5 ft. per min. A cutting speed of less than 1 ft. per min. would have been preferable, but sufficient power was not available to remove the chip at such a low speed, since the belts would slip. The ideal way to carry on an experiment of this kind would be to have the milling-machine spindle geared to the motor through the proper reduction gears, thereby making a positive drive.

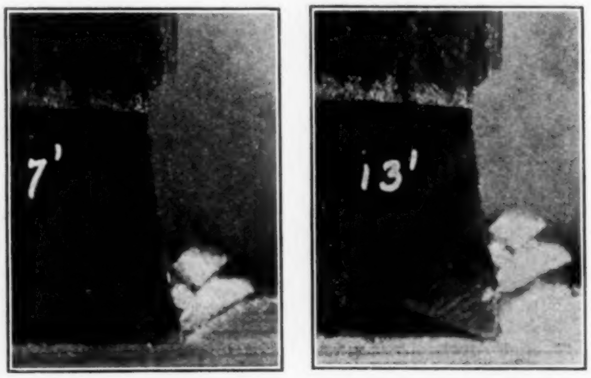


Fig. 2 Two of a Series of Fifteen Photographs of a Cut Taken by a Tool Having a Rake Angle of 20 Deg.
(Here the cut is heavier than in Fig. 1, being 0.125 in. in depth, and the angle of shear is 31¹/₂ deg.)

Paraffin and lead were first employed as test materials, but the former crumbled under the pressure of the cutter and the latter proved to be too soft for experimental purposes. Babbitt metal, however, was found to be satisfactory, and a comparison of chips from this alloy and from steel showed that the cutting action was the same in both cases.

Tests were made with rake angles of the cutter ranging from 0 deg. to 20 deg. with the results indicated in the typical photographs reproduced in Figs. 1 to 3.

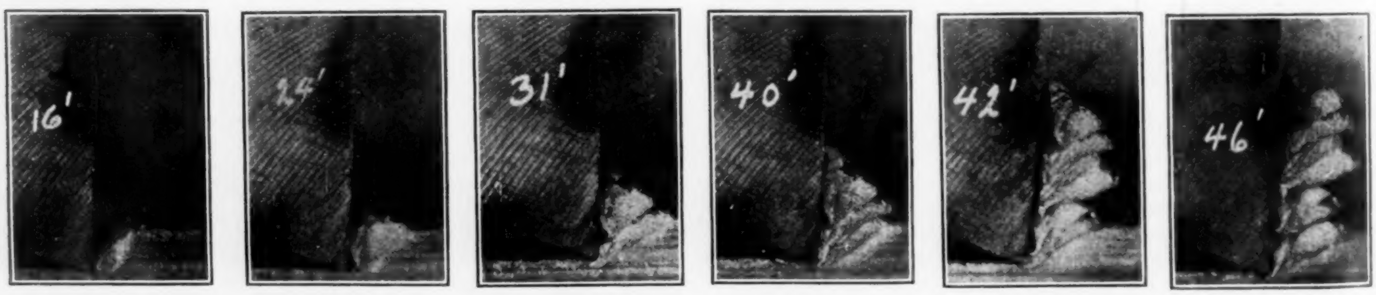


Fig. 3 Stages in the Formation of a Chip by a Tool Having a Rake Angle of 0 Deg.
(Depth of cut, 0.125 in.; angle of shear, 28 deg.)

From a study of the actual formation process of the chips, and of photographs of the process, the author deduces the following conclusions:

The tool compresses the metal until the load is sufficient to shear a chip off as shown in the accompanying illustrations. After this slip has taken place, the point of the tool slides over the surface and gives it a finish. While the metal is being compressed, it is deformed and spreads out over the face of the tool. If a heavy cut is taken, this lateral strain becomes great enough to split the chip before it shears off. A small rake angle on the tool has a tendency to cause the same action. After one chip is sheared off another begins to form, and the preceding chip slips over the tool and away from the work. This slipping action is accompanied by a slight turning action, and the two combined cause the tool to wear away on the face, just back of the cutting edge. The size of the chips depends upon the kind of metal cut, the depth of cut, and the cutting speed. In the case of a soft, ductile metal such as steel, the section or chip which is sheared off does not drop away but is held in place by properties inherent in the metal, and a succession of these chips curl off and form a long shaving. Cast iron, however, acts differently, the chips dropping away directly they are sheared off.

As far as the author was able to observe, there was no crack preceding the point of the tool, except at the point of shear. The angle at which shear takes place varies with the material, the depth of cut, and the rake angle of the tool. This angle increases as the cut deepens and as the rake of the tool is increased. As this angle increases the area of shear becomes less, and therefore the shearing stress becomes smaller. This may account for the fact that a thick chip is removed with less power than a thin one. This is probably true only up to the point at which the chip begins to split and crumble, after which power is wasted in deforming the chip.

Abstract of a thesis presented by the author to the faculty of the College of Engineering of the University of Cincinnati in part fulfillment of the requirements for the degree of mechanical engineer.

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The Development and Importance of Preferred-Number Series[1]

By HILDING TÖRNEBOHM, STOCKHOLM, SWEDEN

ALL MODERN standardizing in the mechanical branch of industry is theoretically based upon series of numbers. The success of such standardization depends upon our ability to select an adequate series of numbers for each case, and the question of devising certain series which will fulfil the general requirements is now under consideration. The advantages to be gained from this procedure are that the numbers will be repeated; there will be a minimum number of tools of all kinds; workmen will get used to the designating numbers and will soon recognize that if another number is introduced it is to care for an extraordinary case; and those charged with the work of standardizing will in most cases know the numbers they will have to use. The construction of these series of numbers is evidently of great importance. It must not be forgotten, however, that we are hampered to a certain extent by the common practices of manufacturing, which are very often far from the ideal. A study of such series of preferred numbers and how they may be constructed will be the object of the following discussion.

The simplest of all series is the normal succession 1, 2, 3, 4, 5, 6, 7, 8, 9, and so on. If this series were always employed, all decimals would disappear. We have also to consider other than metric series, for instance, one for screw diameters, specified in inches, which will give figures ending in decimals if they are converted into millimeters. Since the above-mentioned series has very small intervals, at least for the practical manufacturing of articles of large size, it is not an ideal one for standardizing purposes. The desired economies would not result if the manufacturing were done according to a series whose intervals were smaller than necessary.

It is generally the case in standardizing that a fixed amount cannot be taken as the difference between the successive sizes in a series of articles of the same kind. The difference must be specified in percentage of the size, which indicates that a series used for standardizing purposes ought to be geometrical instead of arithmetical.

It may be asked if the geometrical series can be recommended in all cases, or if not, how the series used in standardization should be built up.

If the different numbers in a series are laid out along a line, as OX, Fig. 1, the numbers will be represented by the lengths L_1, L_2, L_3, etc. Suppose that for a certain size it is desired to use a dimension represented by the length L. This dimension, which may have been obtained by calculation according to the strength of the material, lies between L_n and L_{n+1}. If now it is desired to use a standard size, it will be necessary to employ either L_n or L_{n+1}. If the dimension L was very closely calculated, it is possible that the dimension L_n cannot be allowed, in which case L_{n+1}, will have to be used, or one larger than needed. This will result in a loss if the larger size, being a standard one, is not just as cheap or cheaper than the L, which would have to be manufactured specially.

If the article with the dimension L could be manufactured in the same way as if the dimension were L_{n+1}, it would certainly mean a loss were we to use the latter. This loss would, to a certain extent, be represented by the distance $L_{n+1} - L$ and the maximum value it could reach would be $L_{n+1} - L_n$, which would be when $L = L_n$.

If the cost of a certain detail of a standard size with its principal dimension $= L_{n+1}$ be denoted by $f_m(L_{n+1})$, and the cost of the same kind of an article of a special size with its principal dimension $= L$ by $f_s(L)$, and if it be assumed that the difference between the principal dimensions of two articles of standard size will have to be of such an amount that it will not pay to manufacture a special size in between two standard sizes, the following limiting equation can be written:

$$f_m(L_{n+1}) = f_s(L_n)$$

This equation gives the largest amount of the difference between the principal dimensions of two articles of standard size that is consistent with economical production.

For convenience make the principal dimension L_{n+1} equal to $L_n + a_n$. The interval at L_n is then represented by a_n and the equation will be

$$f_m(L_n + a_n) = f_s(L_n)$$

Without serious error it can be assumed that

$$f_s(L) = k\,f_m(L)$$

which implies that the cost relation between a standard article

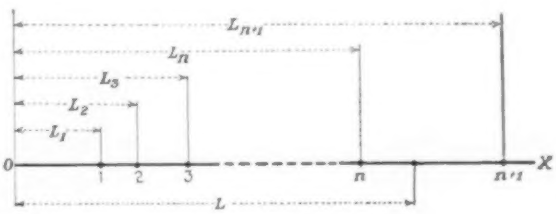

Fig. 1

of a given size and a special article of the same size is constant for all values of L. Whence

$$f_m(L_n + a_n) = k\,f_m(L_n) \qquad [1]$$

The constant k can evidently be modified so that the equation will serve for general conditions as well as for maximum. It will then hold good for all standard values of L.

It would be possible to make up a standard series, by substituting suitable constants in Equation [1], and then solving for a in terms of L. Such a procedure would of course be somewhat laborious, but the intention is not to use the equation in practice but to derive certain general rules by studying one or two special cases.

Assume that the costs for a series of a given kind of article are in proportion to the main dimensions. This supposition is valid, especially when all dimensions of the articles except the principal ones are constant, these latter being variable. For example, if $^3/_8$-in. screws of a certain kind are to be standardized with regard to their lengths, the principal dimension in this case will be the length L, and we can write

$$f(L) = AL + B$$

Equation [1] will then read

$$A(L + a) + B = kAL + kB$$

or

$$a = (k - 1)L + \frac{B}{A}(k-1) \qquad [2]$$

Equation [2] is that of a straight line.

If in Fig. 2 the first dimension is L_1, L_2 and L_3 are obtained in the way there indicated.

Taking another example, let it be assumed that the cost varies along the curve of an equation of the second degree. Then

$$f(L) = AL^2 + BL + C \qquad [3]$$

[1] The principles set forth in this comprehensive discussion of the subject of preferred numbers are accepted by the Sveriges Maskinindustriförenings Standardkommission (Standards Commission of the Swedish Machine Trade Association), of which the author, a civil engineer, is a member and Mr. Erik Fornander the secretary. The A.E.S.C., which received this discussion and has transmitted it to MECHANICAL ENGINEERING for publication, points out that it is the first one to give quantitative consideration to the economies obtainable through the adoption of preferred-number series.

If this value of $f(L)$ is inserted in Equation [2], it will be found that the value of a often varies along the branch of a hyperbola, as is shown by the dotted line in Fig. 2.

Assuming that the function varies along the curve of an equation of the third or fourth degree, values will be obtained which follow the above-mentioned branch of a hyperbola very closely. The branch of a hyperbola approaches a straight line, which indicates that the intervals ought to form a geometrical progression.

In constructing series of a geometrical nature, mixed numbers often result. Naturally when arranging a standard series it is desirable to use only whole numbers, and one way of doing this is to round off the mixed numbers to the nearest whole numbers. For the purpose of developing a law for selecting numbers and in

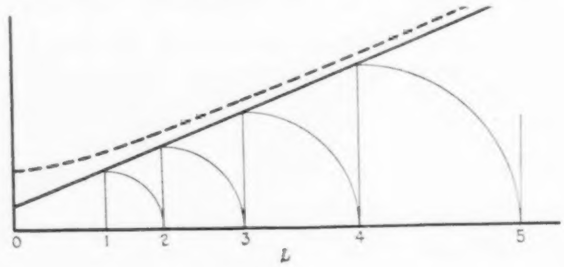

FIG. 2

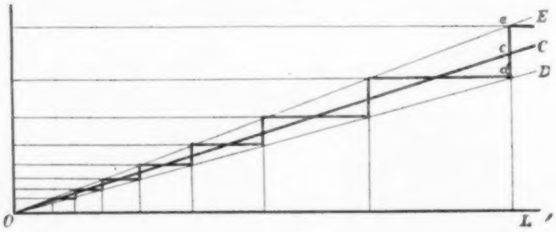

FIG. 3

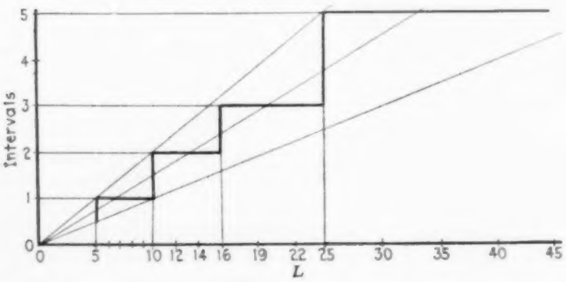

FIG. 4

addition providing for the introduction of specially preferred numbers into the series, the following method can be recommended.

In Fig. 3 the straight line OC represents the costs. This line passes through the origin O, as obviously the cost of an article of zero dimension must be nothing. On both sides of the line OC other straight lines OD and OE are so drawn that they intersect any ordinate at equal distances above and below the line OC, that is, $dc = ce$. These two lines can very well serve as limits for the departure from the straight line OC. It is seen then that the departure at any value of L will be a constant percentage of L.

The Swedish Standards Commission has, in selecting a series of numbers for lengths, proceeded in the above-mentioned manner. The result is the following series: 5, 6, 7, 8, 9, 10, 12, 14, 16, 19, 22, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 120, 140, 160, 180, 200 . . . etc. (see Fig. 4). It may not appear rational, when we are uncertain as to the constants which have to be used, to devise a series in this way, but we must bear in mind that systematization is necessary in all standardization, otherwise we would have to expect changes as a consequence in the future. Changes, however, may become necessary for any number of reasons. This series has been tried out for a number of years in Swedish works with good results, but of course it may eventually become necessary to introduce a few additional numbers.

The German Standards Commission has without hesitation adopted the idea that series for standardizing purposes ought to be geometrical. The German solution of this problem, which must be considered a very good one, especially in the case of type standardization, is simply that $\sqrt[10]{10}$ is taken as the ratio in the geometrical progression. The reason why this ratio is selected is that the tenth term will be ten times as large as the first term. The series is as follows:

1	10	100
1.2	12.5	125
1.6	16	160
2	20	200
2.5	25	250
3	30	300
4	40	400
5	50	500
6	64	640
8	80	800
10	100	1000

In addition to the foregoing series, Germany has introduced others[1] having the ratios $\sqrt[6]{10}$, $\sqrt[20]{10}$, and $\sqrt[40]{10}$. As the extremes in all these series are either 1 and 10 or 10 and 100, some of the mean terms will be alike.

In the standard sheet DINORM 323 Bl. 1, issued by the Normenausschuss der Deutschen Industrie, it is specified that the series with the ratio $\sqrt[6]{10}$ (1, 1.6, 2.5, 4, 6, 10, 16, 25, etc.) shall be used wherever it is possible. When not, the next series, ratio $\sqrt[10]{10}$ (1, 1.2, 1.6, 2, 2.5, 3, 4, 5, 6, 8, 10, etc.) is to be considered. If a series with still smaller intervals is desired, the series with the ratio $\sqrt[20]{10}$ may be used. The last series, with the ratio $\sqrt[40]{10}$, has such small intervals that its first term is 10, and it will naturally be used only in extreme cases. It is further stated on the standard sheet that these four series are to be used in the standardization of different sizes of machines of the same type, apparatus, buildings, etc., but for normal finished diameters another is recommended.

In the opinion of the author, the German series have but one defect, which is that the number 12.5 has been considered necessary in the $\sqrt[10]{10}$ series; however, a rounding off of this number to 12 would bring about uneven steps in the $\sqrt[40]{10}$ series.

It has been stated that different purposes call for different series, such as series for standardization of types, of normal diameters, and of lengths. What, it may be asked, is the difference between these series, and why should not one series be sufficient? From the author's point of view it is quite necessary to distinguish between the various series used for standardization on account of the entirely different character of the subjects standardized.

A single example will show that geometrical series alone are not enough for standardizing purposes. The values of our coins form a standard series which is not and could not be geometrical. The stipulation for the coin series is that the sum of two or more coins must equal the value of a larger coin. This result cannot be obtained by a geometrical series.

The following classification of the various series required in standardization work will be of interest.

1 *Series for Types.* These series have to be used for standardizing principal dimensions such, for example, as diameters of threads, diameters of pulleys, internal diameters of ball bearings, machine tools, candlepower of incandescent lamps, output of motors, etc. The German series are applicable for this group of standards but cannot cover all cases, some exceptions being diameters of threads, diameters of pipes, etc.

2 *Series for Lengths.* These series are suitable for standardizing different sizes within each type; for example, lengths of screws, lengths of threads, widths of pulleys, etc.

3 *Series for Normal Diameters.* These series are usable for standardizing gages for diameters. A series of normal diameters is intended for the purpose of reducing the number of such tools.

(*Continued on page 613*)

[1] The numbers of these series are given in Table 4 of the paper on Size Standardization by Preferred Numbers, by C. F. Hirshfeld and C. H. Berry, in MECHANICAL ENGINEERING, December, 1922, p. 791.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Nusselt's Coefficients of Heat Transmission and Their Range of Application

By ALFRED SCHACK

THE author discusses the coefficients of heat transmission previously determined by Nusselt, the mean temperature of a cross-section, and the mean true temperature of a stream of liquid or a gas. He criticizes the precision of Nusselt's experiments and offers practical methods for measuring quantities of heat.

If t_R is the temperature of the inner wall of a pipe, t_G the temperature of the fluid (gas or liquid) flowing through the pipe, then the amount of heat transmitted per hour per square meter of surface from the pipe to the gas or vice versa is

$$Q = \alpha \times (t_R - t_G) \text{ (cal. per sq. m. per hour)} \quad \ldots\ldots [1]$$

where α is the coefficient of heat transmission.

Contrary to views formerly held, it has been found that this coefficient is not only not constant but is highly complicated and has been until now an imperfectly known function of the properties of the fluid, pipe, velocity of flow, etc. W. Nusselt in 1909 was the first to throw a clear light on the nature of this coefficient.

The author claims, however, that both Nusselt and his successors have failed to take into consideration certain factors affecting the precision of measurement of temperature. The temperature is not at all uniformly equal through the cross-section of the pipe and neither are the components of velocity in a turbulent flow lying in the direction of the flow. When the temperature of the gas is lower than that of the pipe the layers of gas lying nearest the wall of the pipe are hottest, and yet the velocity of flow of the gas there is zero.

On the other hand, it is obvious that the amount of heat carried off per hour by the gas through any part of the cross-section of the pipe is proportional to the velocity and temperature of the particles flowing through the given cross-section. If, therefore, it be assumed that contrariwise to the conditions in the Nusselt test the gas is hot while the pipe is cold, the amount of heat flowing through the cross-section will be obviously different from that which will flow in the case where the pipe is hotter than the gas, and will be different notwithstanding the fact that in both cases the mean temperature of the cross-section, the velocity of flow, and all the other conditions are equal. The velocity distribution may be equal in both cases, the temperature distribution is not. When the pipe is hot the temperature of the gas reaches its maximum near the pipe wall and its minimum in the interior, while the contrary prevails when the gas is hot and the pipe is cold.

If the products of velocity and temperature in the various parts of a cross-section are obtained and added up, it will be found that the flow that carries the greatest amount of heat through a given cross-section is one in which the maximum temperature is in the inside of the pipe, since in that case the maximum of temperature coincides in locality with the maximum of velocity of flow. With the same mean value of temperature through a cross-section, the same velocity of flow, the same dimensions of pipe and the same gas, the amount of heat carried through a given cross-section per hour will be greater in the case of a pipe that is colder than the gas than in the case of one that is hotter.

The most significant thing in both cases is, however, that in neither of the two will the "true heat" carried through a given cross-section be found by a process of multiplying the correctly determined mean temperature of a cross-section by the correct velocity of flow and the correct specific heat of the gas. In the first case excessively large, and in the second case excessively small, heat values will be found. It therefore becomes necessary to introduce a new kind of average temperature of gas which the author calls the "true mean temperature," which, when multiplied by the velocity and specific heat of the gas, will give the amount of heat actually flowing through a pipe cross-section, irrespective of whether the pipe wall is colder or warmer than the fluid passing through the pipe.

It was Gröber who first called attention to the existence of a difference between the mean temperature t_Q of a cross-section and the true mean temperature t_G of a gas stream. He found that the Nusselt values deviate from the true values by as much as 40 per cent. Gröber claimed that the Nusselt coefficient of heat transfer was improperly expressed. Actually, however, it is not the definition of heat transfer, which is purely arbitrary, but the method of measurement used by Nusselt that is answerable for the incorrect results.

The present author claims that it can be shown that even with the constant α which Nusselt used, his results would have been quite close to the true values if only he had used a pipe that was colder than the gas, and had thus worked with the direction of heat transfer opposite to that which he actually had in his tests. By employing as a foundation the theories of Prandtl and Von Karman an expression may be derived for the difference between the "true mean" gas temperature and the mean temperature of a cross-section, namely,

$$t_G - t_Q = \frac{1}{72}(t_A - t_R) \quad \ldots\ldots\ldots\ldots\ldots\ldots [2]$$

where t_A is the temperature of the gas at the axis of the pipe and t_R the temperature of the pipe wall, both in degrees centigrade. From this expression it would appear that, contrary to the opinion of Gröber, the values in the individual tests of Nusselt are at most 6 per cent too high, and in the majority of instances considerably less in excess of the true values. The case would have been the same had Nusselt in his measurements actually determined t_Q instead of t_G. He did not do this, however, and an entirely new situation is thus created. For his measurement of temperatures Nusselt used a spirally wound resistance thermometer which did not touch the pipe wall. It may be shown that on account of this a temperature was measured which is materially nearer the true mean temperature t_G than the mean temperature of cross-section t_Q. Furthermore, since Nusselt did not find any appreciable effect of the influence of the pipe length, i.e., the distance between the two points of measurement, it may be concluded that the temperature which he measured lay quite close to t_G. It may further be shown that the radiation from the hot pipe walls could have caused an error which even under the most favorable conditions did not exceed 1 per cent. Taking everything into consideration, it would be fair to estimate the possible error in the Nusselt formula as being at most under 2 per cent, though it cannot be stated whether the deviation is positive or negative.

It would appear that in experimental measurements such as those of Nusselt the difference between t_G and t_Q is not of great importance. The situation is different at times, in particular in heat measurements on flowing gases and liquids, which are of great importance in metallurgical industries. Here one also has to deal with the true temperature t_G, and the question arises as to what is the correct method of measurement by simple means. If a thermometer properly protected against radiation be placed in the axis

of the pipe, i.e., the place where the highest temperature prevails, a temperature about 12.5 per cent higher than t_G will be obtained ($t_R = 0$). Calculation would indicate that the true gas temperature is a resultant of the temperature at the axis of the tube t_A and the temperature of the wall of the pipe t_R in accordance with the expression

$$t_G = \frac{8}{9} t_A + \frac{1}{9} t_R \qquad [3]$$

This is under the assumption that there is a completely evolved state of velocities and temperatures, and that the measurements are taken at a point several diameters back of the last interruption of a smooth straight pipe. According to Equation [3], t_G may be determined from two measurements, t_A and t_R. It is possible to determine t_G by a single measurement in the following manner. If the cross-section of the temperature field of an undisturbed turbulent flow be plotted and on it be plotted the computed mean true gas temperature t_G, the intersection of the straight line t_G with the temperature curve will be found at a distance $^1/_8$ of a diameter from the wall of the pipe whether the pipe be cooler or warmer than the gas, the diameter here being the inside diameter of the pipe. As it is rather difficult to maintain a distance of $^1/_8$ of a diameter from the pipe wall, it is advisable to err in the direction toward the center of the pipe rather than toward the wall, since in the first case the error is comparatively small while in the latter it is large. In order to determine the true gas temperature in an undisturbed turbulent flow of gas or a liquid, the bulb of the thermometer or the contact point of a thermoelement should be held in the stream at a distance from the wall of the pipe equal to $^1/_8$ of its internal diameter. (In actual practice, however, it is difficult to obtain in the case of pipes of large diameter undisturbed flow of the fluid.)

From this the author proceeds to an investigation of the extent of the field in which the Nusselt formula holds good. In this connection he considers the question whether the Nusselt formula is applicable to such conditions as occur, for example, in metallurgical plants, and comes to the conclusion that it is not. This is due to the fact that the formula is based on the assumption that the drop of temperature at the tube wall in the radial direction is proportional to the product of powers of all the magnitudes on which it is dependent. In order, however, to be able to apply the principle of similarity, it must be further assumed that all the exponents of these variable quantities are constant, and this cannot be done except on experimental proof. Nusselt's own tests have shown that this is so, but only within the range of his experimental work. There is no question but that within a limited range any function may be very closely represented by a power of a variable, but a conclusion should not be drawn from this that further variations of the function may likewise be expressed by the same power. In other words, it should not be assumed that one may safely extrapolate to any degree whatsoever, or that in this expression the true organic law of the function has been found. However, the chances are that in the majority of cases within some different range of the application of the function another exponent will have to be selected for the variable in order to express the functional variation, and the ranges covered by each of these exponents may be of variable extent.

It follows from this general expression that it is quite unlikely that all the exponents expressing the radial drop of temperature at the tube wall in accordance with the Nusselt formula would remain constant even after a material change in the experimental conditions, particularly as the Nusselt formula does not represent the true function with respect to α. It is merely a mechanical approximate formula not capable of extrapolation, intended to express the still unknown physical law. Because of this the availability of the Nusselt formula in no way eliminates the necessity of tests in fields of application where conditions differ materially from those which obtained during Nusselt's own tests. On the other hand, extrapolation is permissible in cases where conditions do not materially differ from those in the Nusselt tests, for example, with smooth pipes up to 10 cm. (4 in.) inside diameter. It should not be applied, however, to the cases of brick-lined passages, etc.

In particular the influence of radiation makes it inadvisable to apply without further reservations the Nusselt formula under certain conditions to the case of hot gases containing water vapor or carbon dioxide. Contrary to what happens with air, carbon dioxide and water vapor and possibly the majority of other triatomic and polyatomic gases are not entirely transparent to dark radiations. Their absorption (the original article gives some figures) depends on the wave length and is roughly of the order of 50 per cent of the total radiated energy. (Abstract of a more extensive investigation by the author in preparation for publication. Abstracted through *Stahl und Eisen*, vol. 43, no. 29, July 19, 1923, pp. 942–946, *tA*)

Short Abstracts of the Month

AERONAUTICS (See Internal-Combustion Engineering)

ENGINEERING MATERIALS (See also Railroad Engineering)

Some Compressive Tests of Hollow-Tile Walls, Herbert L. Whittemore (Mem. A.S.M.E.) and Bernard D. Hathcock. The Bureau of Standards has published the results of tests of hollow building tile in its Technologic Paper No. 120. The work was done in coöperation with committee C-10 on hollow building tile of the American Society for Testing Materials. As the strength is important when built into a wall, similar tile were used in constructing 32 walls each 4 ft. long, 12 ft. high, and either 6, 8, or 12 in. thick. The National Fire Proofing Company donated all the tile, which were of such design that all the net area was in bearing when carefully set on end in the wall. As the strength of these tile was greater than the strength of the average tile used in buildings, the results of this investigation should be used with discrimination.

The mortar used was a mixture of the following proportions: 1 cu. ft. of portland cement, $^1/_4$ cu. ft. of hydrated lime, and 3 cu. ft. of sand dried in an oven. The walls were laid with great care by an experienced mason, and were of much better workmanship than is usually obtained.

The walls were, with a few exceptions, tested when one month old. After placing a wall in the testing machine, it was capped with plaster of paris, the upper head brought into contact with the wall, and the cap allowed to set for 12 hr. or more.

Compressometers were placed at each corner, and readings taken during the test. Stress curves were drawn to show the behavior of the walls. Strain-gage readings were also taken, both on the tile and across the horizontal joints. Due to the great differences in the modulus of elasticity of the tile and the lack of data on the modulus for the particular tile on which strain-gage readings were taken, these readings were of little use. The horizontal deflections of the walls were measured at midheight of the walls.

The following conclusions may be drawn from the results of the tests:

a Although the strength of the individual tile in lot A was about twice that for the tile in lot B, the strengths of the walls made from these tile were only slightly greater.

The ultimate strength of the walls made from the A tile averaged about 37 per cent of the strength of the individual tile, while those made from the B tile averaged about 55 per cent.

b From the theory of columns, it might be expected that a thick wall, the height being the same, would sustain a greater load than a thin one. These tests, on the contrary, show no effects that can be definitely ascribed to "column action." This is confirmed by the small deflection of the walls.

c Apparently there is no relation between the ultimate strength of a wall and the load at the first crack.

d The walls having the cells of the tile vertical had, on the average, more than twice the strength of those having the cells horizontal. For both these cases the values of the stress at failure were remark-

ably constant, being apparently independent of the size of the tile. The ultimate stresses computed on the net sectional area were also somewhat greater for the walls having the cells vertical, except for the 6-in. A tile, for which the stresses in the walls having the cells horizontal were slightly greater. Apparently the advantage of setting the tile with the cells vertical is greater for eccentrically loaded walls than for walls which are axially loaded.

e In only one case could a direct comparison be made between "broken" and "unbroken" joints. Wall No. 31 with "broken" joints, but in all other respects identical in construction with walls Nos. 25 and 26, which had "unbroken" joints, shows a much higher strength. Conclusions, however, should not be drawn from the results from one specimen. Attention is called to the fact that in these tile the transverse webs were spaced to give full bearing over the end of the tile when the cells were vertical and the joints "broken," as well as when the joints were "unbroken."

f For the axially loaded walls, the failure was sometimes by crushing at the top and sometimes by vertical cracking through the joints. No consistent difference in strength was found for these two types of failure. Probably the crushing at the top was determined by the plaster cap, which was somewhat weaker than the mortar joint.

g Walls loaded with an eccentricity of 2 in. over one-half the width of the wall had about one-half the strength of similar walls axially loaded. Apparently this ratio is independent of the thickness of the wall. The maximum deflection for the eccentrically loaded walls was, on the average, 0.04 in., undoubtedly a very small value, which was exceeded by six of the axially loaded walls.

h Failure, in the case of the eccentrically loaded walls was local. The upper bearing plate rested on two of the webs of each tile in the upper course. The stress in these webs was therefore much greater than in the lower courses in which the load was more uniformly distributed.

i The modulus of elasticity of the walls varied over a wide range, and apparently there is no relation between the modulus for the wall and that for the individual tile.

j Due to the wide variations in the moduli of elasticity of the tile and in the deformation of the joints, it seems probable that failure of a tile wall is caused by the unequal distribution of the stresses. Therefore any means of securing a more uniform stress distribution, such as selection of tile having the same physical properties and setting them with a uniform thickness of joint, would be expected to increase the strength. (Abstract of *Technologic Paper of the Bureau of Standards*, no. 238, *e*)

Invar and Related Nickel Steels. This circular of the Bureau of Standards is mainly a compilation of data obtained during the last 30 years by various investigators of the different properties of nickel steels. Particular attention is given to "invar," a nickel-iron alloy containing about 36 per cent nickel and possessing an extremely small thermal expansivity at ordinary temperatures, the mean coefficient of linear expansion between 0 and 40 deg. cent. being on the order of 1 to 2 millionths. The results of investigations made on the various properties of the nickel-iron alloy series are presented largely in diagrammatic and tabular form.

The anomalous behavior in the thermal expansion of nickel-iron alloys at various temperatures is illustrated by a number of diagrams. The degree of thermal expansivity reaches a minimum in alloys with about 36 per cent nickel (and 0.4 per cent manganese and 0.1 per cent carbon), and the position of this minimum may be modified by the presence of added elements as chromium, etc., and also by thermal or mechanical treatment.

The thermal conductivity and specific heat of nickel-iron alloys show minimum and maximum values, respectively, at about 35 per cent nickel.

Some data on the mechanical properties and also Brinell and Shore scleroscope hardness numbers of nickel steels with the nickel content ranging up to about 50 per cent are given in both tabular and diagrammatic form. The tensile properties of invar may run as follows: Tensile strength, 50,000–100,000 lb. per sq. in.; elastic limit, 30,000–70,000 lb. per sq. in.; elongation, 25 to 50 per cent; and reduction of area, 40 to 70 per cent.

Nickel steels present anomalies in the elastic modulus corresponding closely to those found in thermal expansion. It has been found that the degree of anomaly can be reduced in very large measure by means of suitable additions made to the alloy, namely, about 12 per cent chromium or its equivalent, this alloy having recently been introduced under the trademark "elinvar." This is of practical importance in the construction of watches and chronometers, where the degree of error with variations of temperature and consequent need for compensation may be made very small.

Resistance to corrosion by fresh and sea water and acid liquors increases with the proportion of nickel. An alloy containing about 18 per cent may be regarded as practically non-corrodible. The resistance of invar to oxidation, while very much greater than that of ordinary steel, is not perfect, therefore it is advisable to coat an invar instrument with a protective coating such as vaseline if it is to be exposed for a long time in a moist atmosphere.

The extent and nature of applications of nickel steels are discussed. A list of makers of nickel steels and dealers in nickel steels of minimum thermal expansivity in America and also a selected bibliography are included. (*Abstract of Circular of the Bureau of Standards*, no. 58, 2nd edition, *de*)

FOUNDRY

Pressure System of Pouring in a Non-Ferrous Foundry, Roy E. Paine. Data on a process for making castings without risers or feeding heads, developed in a brass foundry in San Francisco:

In this case the metal is poured through a square gate at the bottom, and usually a small horned gate is used. This is connected to a vertical gate about twice the diameter of the bottom gate and extending 18 in. above the top of the casting. Of course greensand molds must be rammed firmly to withstand the pressure exerted by the metal while in a fluid condition and to prevent the metal from straining or from burning on to the face of the mold. The problem of cores is particularly difficult in connection with the system of pressure casting, but a core mixture has been developed which makes a core that does not burn on and that is removed easily. Temperature of the metal exerts a great influence on the successful application of pressure casting.

It is claimed that the pressure system of pouring castings offers several advantages. It is not necessary to make provision for risers, feeding heads, and heavy gates. Castings do not have to be burned where shrinkage has left large holes at the gate of feeding head. It is also claimed that a denser casting is secured and that costs of cleaning are reduced. (*The Foundry*, vol. 51, no. 14, July 15, 1923, pp. 559–561 and 597, 10 figs., *d*)

Die Castings for Owen Sound Plant, Herbert Chase. Data of the practice in the plant of the Stewart Manufacturing Corporation building die-casting machinery for the Aluminum Products Manufacturing Co., Owen Sound, Ont., and also in the plant of the latter company.

Three general types of die-casting machines are employed: a horizontal type used chiefly for the smaller castings made in other than aluminum-base alloys, a vertical type used for larger castings of the same character, and an aluminum machine used entirely for aluminum-base castings. The three types operate on the same general principle, but are quite different in appearance. All types have the following essential parts: two members for carrying the two halves of the die, so arranged that the dies can be held closed under considerable pressure during the casting operation and then quickly opened to eject the casting; two core carriers, usually arranged to move at right angles to the direction of motion of the dies; and a metal pot arranged to be moved up to the die, or the die up to it. Each type has somewhat differently arranged means for controlling the motion of the various parts.

The operation of these types is described in some detail. The machine for casting aluminum alloys is different in appearance from the other machines but is substantially identical in principle. The halves of the die are pneumatically operated in this case, but instead of moving the metal pot up to a stationary die, the entire head of the machine containing both the die and its operating mechanism is moved up to a stationary metal pot. The metal pot is

closed and sealed to reduce oxidation and contains the molten aluminum at a temperature of about 1500 deg. fahr.

In connection with the design of parts to be die cast the following points should be borne in mind:

1 Avoid undercuts on inside surfaces so far as possible.

2 Allow, in the case of aluminum, for a draft of 0.005 in. per in. of length and of diameter of cores. On white-brass cores allow a draft of 0.002 to 0.003 in. per in.

3 Uniformity of section tends to prevent cracking. When thick and thin sections are necessary, the transition from one to the other should be as gradual as possible.

4 Allow fillets whenever possible. Even a very slight fillet is better than none at all.

5 The minimum thickness of section practicable varies considerably with the area of the section. One-sixteenth of an inch is usually the practical minimum in the case of aluminum and $^1/_{32}$ in. in white brass, but thinner sections have been cast in some cases.

6 The minimum size of hole which it is practicable to cast in aluminum is about $^1/_{16}$ in. when the hole is not more than $^1/_4$ in. deep, or $^3/_{32}$ in. for a hole $^1/_2$ in. deep. In the case of white brass a $^1/_{16}$-in. hole is practicable if the length does not exceed $^1/_2$ in., while a $^2/_{32}$-in. hole of almost any length can be cast readily.

7 The use of knife edges should be avoided.

(*Canadian Foundryman*, vol. 14, no. 7, July, 1923, pp. 20–22 and 27, 3 figs., *dp*)

FUELS AND FIRING (See also Power-Plant Engineering, Testing and Measurements)

Surface Combustion and Radiophragm Heating, Prof. Wm. A. Bone. This paper opens with a brief historical account of the development of surface combustion, including the work of the author and that of the late C. D. McCourt.

One of the recent developments in this direction is that of the radiophragm. This is based on a process developed by the author and his collaborator McCourt in 1909, in which a homogeneous mixture of gas and air in the right proportions for complete combustion was made to flow from a suitable feeding chamber at the back to a porous diaphragm of refractory material and caused to burn without flame at the surface of exit, which was thereby maintained in a state of red-hot incandescence. The recent improvements lie in the new methods of manufacturing the radiophragm itself.

The actual method of making these radiophragms, however, is not described and only general statements as to tests are made concerning them. It is said that they are used for cooking and that there have also been constructed and are at present on trial appliances for lead melting, type founding, hardening and tempering of metals, and other purposes.

An extensive reference is also made to surface-combustion boilers, but no new data in this connection are presented. (*Jour. Royal Society of Arts*, vol. 71, no. 3686, July 13, 1923, pp. 596–601 and discussion 601–611, 6 figs., *dg*)

Comparative Tests of By-Product Coke and Other Fuels for House-Heating Boilers, Henry Kreisinger, John Blizard, H. W. Jarrett (Members A.S.M.E.), and J. J. McKitterick. One of a series of reports published by the Bureau of Mines for the purpose of disseminating information regarding the fuels best adapted for heating houses. It gives the result of tests that were made to compare by-product coke, bituminous coal, and anthracite as fuels for small boilers.

A brief summary of the results is given in a table which shows that the efficiency was as high with by-product coke as with anthracite. In fact, the two Capitol boilers gave somewhat higher efficiencies with coke than with anthracite. The efficiencies obtained with Pittsburgh and Illinois coal were 8 to 20 per cent lower than that obtained with by-product coke.

The Pittsburgh tests showed that about 10 tons of Pittsburgh coal was equal to 9 tons of coke or $8^1/_2$ tons of anthracite when the fuels were burned in the Arco boiler; and to 10 tons of coke or 9 tons of anthracite when burned in a Dunning boiler.

The Minneapolis tests showed that about 10 tons of Illinois coal was equal to $7^1/_2$ tons of coke or anthracite when burned in the small Capitol Winchester boiler, and equal to $8^1/_2$ tons of coke or anthracite when burned in the larger Capitol boiler.

With the same attention to the fire, coke gives a much more uniform temperature than bituminous coal. In addition, coke is a clean fuel and makes neither smoke nor soot, an advantage difficult to express in exact figures. It is nearly as good a fuel as the domestic sizes of anthracite, and if anthracite is unavailable at reasonable prices a by-product coke makes a good substitute. (*Technical Paper no. 315 of the U. S. Bureau of Mines*, May, 1923, 21 pp., 8 figs., *p*)

Explosive Tendencies of Pulverized Coal, Hartland Seymour. The author calls attention to the hazards which arise in connection with the utilization of pulverized coal, stating at the same time that little danger is involved provided reasonable care is taken to comply with well-established precautions.

Powdered coal in bulk is not especially explosive, but when raised in a cloud it is as dangerous as a nozzle discharging gas into the open air. One form of coal dust which is exceedingly dangerous and to which perhaps too little attention is paid is that coming from small heating furnaces in which pulverized coal is used as a fuel. These furnaces are comparatively small and are used principally to heat bars and rods for forgings.

The pulverized coal is shot under pressure, and some of it is apt to get out into the surrounding atmosphere as flowing dust and finally settle all around the place.

A rather peculiar accident happened some time ago from dust of this kind in one of the Pittsburgh steel mills. At one point in the building an electric switch was so situated that dust could settle between the poles. One Sunday, when the mill was shut down, sufficient dust accumulated to form a short-circuit, and as a result a whole panel of the switchboard in the power house was burned out. Many accidents have occurred practically all of which were due to the dusty and unclean condition of the buildings. Some risks, however, are more or less connected with the apparatus used in pulverizing the coal and delivering it to the point of consumption; and though it is true that reduction of the fire and explosion risks rests largely with those operating such plants, yet much can be done through proper inspection by well-informed authorities having proper jurisdiction. In order to get an adequate understanding of these risks and their remedies a working knowledge of the methods and machinery used in pulverized-fuel plants is necessary. A brief description of these methods and equipment therefore may be of value.

From these the author proceeds to discuss the chances of explosion in a driers elevating and conveying plant, storage bins, etc. The article is based practically exclusively on American data taken from the Bureau of Mines and the American Railway Association. (*The Chemical Age*, vol. 9, no. 215, July 28, 1923, pp. 82–84, *d*)

FURNACES

Air Circulation in Dry Kilns

Air Circulation in Dry Kilns. Circulation of the air in a dry kiln is a very important factor in the artificial seasoning of wood. Without a controlled movement of the air it is impossible to maintain the proper temperature and humidity uniform throughout a kiln. Evaporation of moisture from the wood cools and humidifies the atmosphere next to the wood. In order that drying may progress it is continually necessary to replace this cooled, moistened air with a fresh supply of warmer, drier air. This can be accomplished only by a good circulation which will remove the moist, cool air from the kiln or will return it to the lumber after it has been warmed and dried.

In any kiln a certain amount of circulation is natural. The heating coils are continually heating the air, and the evaporation of moisture from the wood and heat losses through the building walls are continually cooling the air. The heated air rises. Some of it escapes through cracks at the top of the kiln, and the rest of it enters the lumber where it is cooled as it picks up moisture. The cooled air drops and is recirculated over the heating coils until it is warm enough to rise again.

If flues or vents for the escape of hot air from the kiln and intakes

for the entrance of cold air are provided, the natural circulation can be considerably increased. The kiln, being warmer than the surrounding atmosphere, will act as a chimney, and the draft that is created will speed up the movement of the air inside the kiln. Circulation may be further increased by the use of inspirators, aspirators, or steam-spray lines. A steam jet in the intake duct is a good inspirator. Aspirators may be in the form of a coil of steam pipe in the uptake flue. Steam-spray lines running the full length of the kiln may be installed in the passages through which the air returns from the lumber to the heating coils if the design of the kiln permits. These steam-jet lines act as recirculators and humidifiers. Their successful operation depends upon the removal of certain quantities of air from the kiln continuously, either through flues or through accidental leakage. If the air is not allowed to escape at all it will soon become saturated, and no further drying will take place. The steam-spray lines can be replaced by condensers which will serve to cool the air and at the same time remove some of the moisture from it. The cooled air will then naturally fall and pass to the heating coils as fast as the hot air rises from the coils. This natural system of recirculation does not depend upon changing the air in the kiln to remove the moisture evaporated from the wood. Water sprays of the proper temperature may be substituted for the condensers. Water sprays permit a better control of the humidity and may be directed to produce a higher circulation.

The modern blower kiln produces circulation by mechanical means, usually by a centrifugal blower of the ordinary type, but sometimes by disk fans. The blower draws the air from the kiln through suitable return ducts and then discharges it again into the kiln through inlet ducts. The air is passed over heating coils on the way and its humidity is increased, if necessary, by means of a steam jet. Leakage is usually sufficient to keep the humidity as low as desired, but intakes may be provided for drawing a certain amount of fresh air into the system. This fresh air is comparatively dry, and mixing it with the kiln air displaces some of the moist air and reduces the humidity of the whole.

The internal-fan kiln makes use of one or more rows of disk fans within the kiln itself, and thus obviates the necessity of drawing the air from the kiln and blowing it back again. This arrangement has the advantage that the direction of the air circulation may be reversed simply by reversing the direction of rotation of the fans. This reversal of the circulation increases the uniformity of drying in the kiln.

It is difficult to specify the amount of circulation proper for different kinds of drying. For material which has previously been air dried only a small amount of circulation is necessary. For green material, however, or for any drying in which high humidities must be used, a rather rapid circulation is required. There is a limit beyond which the rate of circulation cannot be increased and maintained uniform throughout the kiln. A circulation rate of at least 25 ft. per min. through the lumber is recommended by the U. S. Forest Products Laboratory for difficult drying. In certain unusual cases, as in the drying of Douglas fir common lumber, circulation rates as high as 75 ft. per min. are found desirable. (*Technical Note No. 199 of Forest Products Laboratory*, U. S. Forest Service, Madison, Wis., Aug. 15, 1923, *g*)

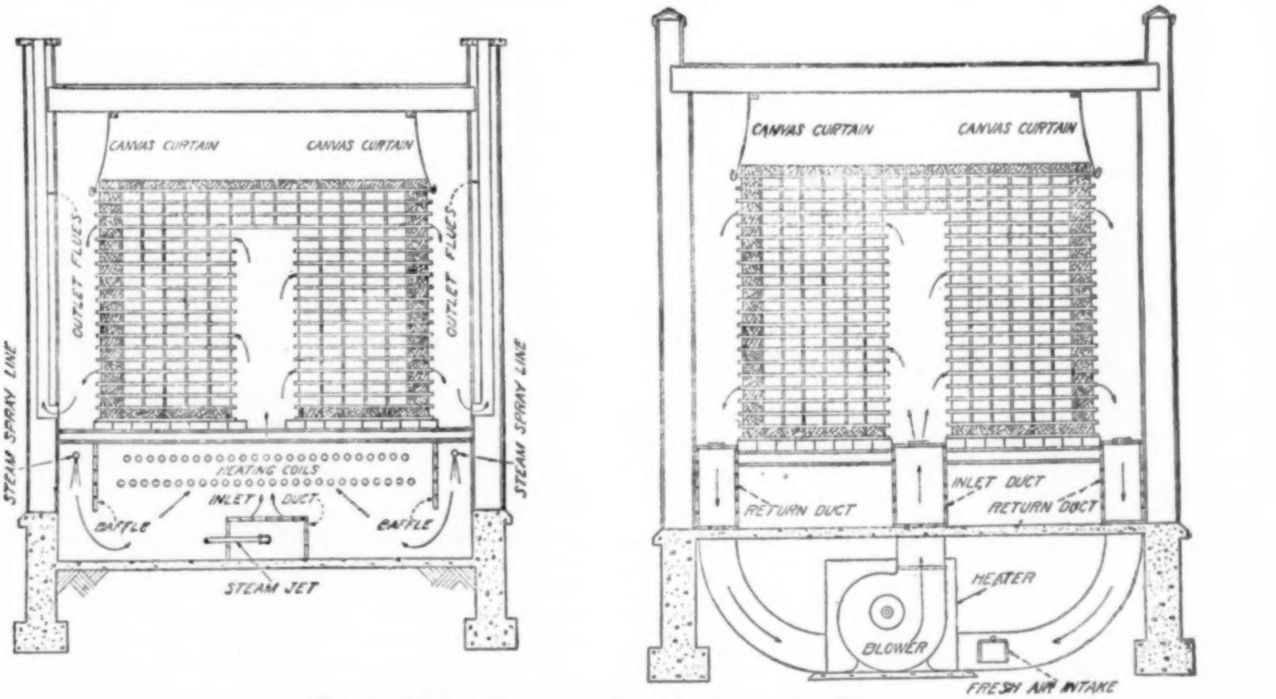

Fig. 1 Types of Ventilated Kilns for Seasoning of Wood

The composite drawing illustrates the various features found in most ventilated kilns. The steam jet in the inlet duct increases the amount of outside air drawn into the system. The steam-spray lines increase the circulation of the air inside the kiln. These spray lines in connection with the inlet ducts and the outlet flues serve to regulate the humidity. The baffles prevent the heated air from rising next to the walls.

The cross-section illustrates the ordinary blower kiln in which an external centrifugal blower produces the circulation. A fresh-air intake on the suction side of the blower can be opened if leakage of air through the walls is not sufficient to keep the humidity below the desired point. Steam jets can be used to raise the humidity if the air gets too dry.

INTERNAL-COMBUSTION ENGINEERING

High-Pressure Oil Engine with Airless Fuel Injection, J. K. E. Hesselman. The Hesselman Diesel engine was briefly described in Mechanical Engineering, vol. 44, no. 8, August, 1922, p. 531, where the details of the fuel-injection valve were given. The present article, however, describes the same engine in considerably greater detail. Among other matters the process of fuel atomization and its mixing with the air together with its subsequent combustion are discussed at length. (*Zeitschrift des Vereines Deutscher Ingenieure*, vol. 67, no. 27, July 7, 1923, pp. 658–662, 16 figs., *d*)

A Diesel Engine of Novel Design

The Knudsen Diesel Engine. An outstanding departure from orthodox design is the adoption in this engine of an inverted V-arrangement of the cylinders and pistons (Fig. 2). Each of the four pairs of V-cylinders has a common combustion chamber with a single injection valve and starting valve. The connecting rods drive parallel crankshafts, one on each side of the engine. At the after end two crankshafts are geared down to a single tailshaft, the speed reduction being in the ratio of 3.8 to 1.

The engine operates on the two-cycle principle, has a scavenging arrangement comprising exhaust ports in one cylinder and scavenge ports in the other, so that the scavenge air sweeps right through each pair of dual cylinders.

The weight of the 100-b.hp. engine recently completed is about 65 lb. per shaft horsepower. The cylinders are of $6^1/_2$ in. in diameter and have a stroke of 9 in., the crankshafts running at about 400 r.p.m.

The use of a combustion chamber in dual cylinders is not new,

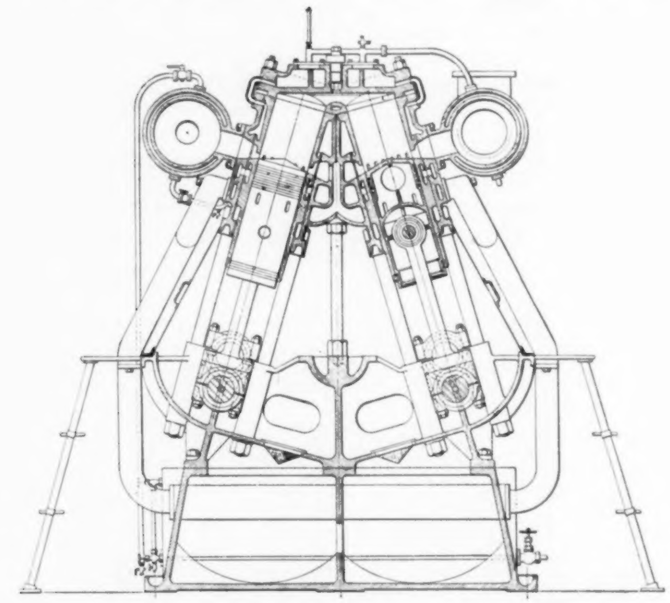

FIG. 2 SECTION THROUGH KNUDSEN DIESEL ENGINE

but the Knudsen engine is said to be the first to combine this feature with an inverted V-arrangement of cylinders and pistons. The engine is of American manufacture. (*Motorship*, vol. 8, no. 8, Aug., 1923, p. 555, 1 fig., *d*)

THE STROMBOLI AERO ENGINE. Peter Hooker, Ltd., of Walthamstow, England, have taken over the British rights for the engine developed by the Italian engineer Stromboli. The engine has been redesigned and developed until it is said today to be virtually a British production. The engine is said to have six cylinders and a total output of 1500 hp. This means 250 hp. per cylinder, which represents a very great advance in aeronautical engineering, as hitherto the greatest output per cylinder—that from the Napier "Cub" engine—has not exceeded some 62 hp. An order has been placed with the manufacturers by the British Air Ministry. (*The Engineer*, vol. 136, no. 3525, July 20, 1923, p. 59, *g*)

MEASURING INSTRUMENTS

OTIS KING CYLINDRICAL SLIDE-RULE CALCULATOR. Description of a calculator of British make. When closed it presents the appearance of a nickel case $1^1/_8$ in. in diameter and $6^1/_4$ in. in overall length. Extended telescope-wise it pulls out to a length of about $10^1/_2$ in. In this condition two spiral scales separated by a sleeve are revealed.

These two scales may be regarded as equivalent to the *A* and *B* scales of an ordinary slide rule, the sleeve representing the cursor and the two indicator marks engraved on it the cursor hairline. The upper scale is twice as long as the lower, but instead of being marked consecutively from 1 to 100, it consists of two identical portions, each covering the range from unity to 10. The lower spiral scale (strictly speaking, that portion of the *A* scale of an ordinary slide rule which extends from unity to the point marked 10) has a total unwound length of about 60 in. and the upper of about 120 in.

The method of operating the calculator and some indication of its accuracy will be gathered by describing a test multiplication made with it. The example chosen was 1.0255 × 1.157, the correct answer to which is 1.1865035. On the ordinary 10-in. slide rule—using the *C* and *D* scales—we can set the sum up as 1.025 × 1.155, the fourth significant figure in each case being estimated. The answer as read is 1.185, the fourth figure again being estimated. On the Otis King calculator the lower indicator mark on the sleeve is set against 1.0255, the fifth significant figure being estimated. The upper tube is then adjusted until the unity mark—either of the first or second half of its scale—registers with the upper indicator mark on the sleeve. This operation is, of course, exactly equivalent to setting the unity mark of the *C* scale of an ordinary slide rule against 1.0255 on the *D* scale. Without moving the relative positions of the two spiral scales the sleeve is now adjusted until its upper indicator mark registers with 1.157 on the upper scale. In this case the fourth significant figure is set up by estimating the mid point between the graduations 1.156 and 1.158. Below the lower indicator mark on the sleeve we read on the lower scale the answer 1.186+. The fourth significant figure is definitely seen to be 6, but the fifth is too uncertain to be estimated. It may be added that five-figure logarithms give the answer as 1.1864, and that six-figure logarithms are required to place the correct value of 5 on the fifth significant figure.

It is important to test the device on the higher portions of the scale as well as upon the lower, and it was therefore tried on the multiplication of 5.435 by 7.375. The ordinary slide rule—*C* and *D* scales—indicates the answer as indistinguishable from 40 dead. The Otis King calculator gives it at 40.1 bare. The correct answer is 40.083.

It seems, therefore, safe to say that this calculator makes it possible in all cases to obtain an answer accurate to one more significant figure than is possible with a 10-in. slide rule. Indeed, its accuracy is very nearly as good as that given by the employment of five-figure logarithms. (*The Practical Engineer*, vol. 68, no. 1898, July 12, 1923, p. 25, 1 fig., *d*)

POWER-PLANT ENGINEERING

Economical Velocity of Superheated-Steam Flow in Piping Systems Supplying Turbines

THE INFLUENCE OF VALVES AND STEAM TRAPS ON THE ECONOMIC STEAM VELOCITY FOR SUPERHEATED-STEAM TURBINES, Prof. O. Denecke. The present article is based on a previous publication by the same author in the German journal *Die Wärme*, no. 8, 1922, under the title The Most Economical Pipe Diameter for Superheated-Steam Plants. It discusses the upper limits of economic steam velocity and in particular the influences which affect the pipe diameter in a superheated-steam plant.

The author's opinions are all based on formulas developed in the article above referred to for the "least" diameter of the steam pipe d_D, which is the diameter insuring the smallest steam consumption, and his formula for the most economical diameter d_b, at which the yearly costs for steam consumption and capital charges are the smallest.

By applying the author's formula to the usual field of superheated-steam turbines it becomes possible to determine the limits of the most desirable steam velocity v_D corresponding to the steam-flow diameter d_D and also to determine the velocity v_b corresponding to the pipe diameter d_b. The author considers in particular the region determined by the following values:

Steam pressure p_a = 16 atmos. and 10 atmos.
Steam temperature t_a = 350 deg. cent.
Output N = 8500 kw. with a steam consumption G = 45,000 kg. per hr. and 750 kw. with a steam consumption G = 5000 kg. per hr.

The author states that his formula and examples show that:

1 The velocities for the smallest steam-flow diameter v_D are lower than the velocities v_b, which latter take into consideration the capital charges in addition to the steam consumption. But even these latter velocities are much lower than the values often quoted in technical literature such as 80 to 100 m. per sec. (262.4 to 328 ft. per sec.). As a matter of fact, even in the most favorable cases, which occur quite seldom, v_b = 48 m. per sec. (157.5 ft. per sec.)

2 The economical velocity of steam v_b is the higher
a The higher the steam temperature t_a
b The lower the boiler pressure, and
c The smaller the turbine.

3 For a turbine of a given output N, a given steam pressure p_a, and a given steam temperature t_a, the economical velocity of steam is the higher the smaller the sum of individual resistances, $\Sigma\zeta$, corresponding to 1 m. (3.28 ft.) of the total length of piping

(l). Since in well-arranged piping the individual resistances consist mainly of valves and steam traps, it would appear that the velocity of steam and the pipe diameter are determined practically exclusively by the number of resistances and the cost of the steam shutting-off devices.

In order to make clear the remarkable influence of these devices, four cases have been investigated dealing with two sizes of turbines having outputs N = 8500 kw. and N = 750 kw., and two initial steam pressures p_a = 16 atmos. and 10 atmos. with the same steam temperature 350 deg. cent. It is also assumed that the total length of the piping is the same, namely, l = 50 m. (164 ft.).

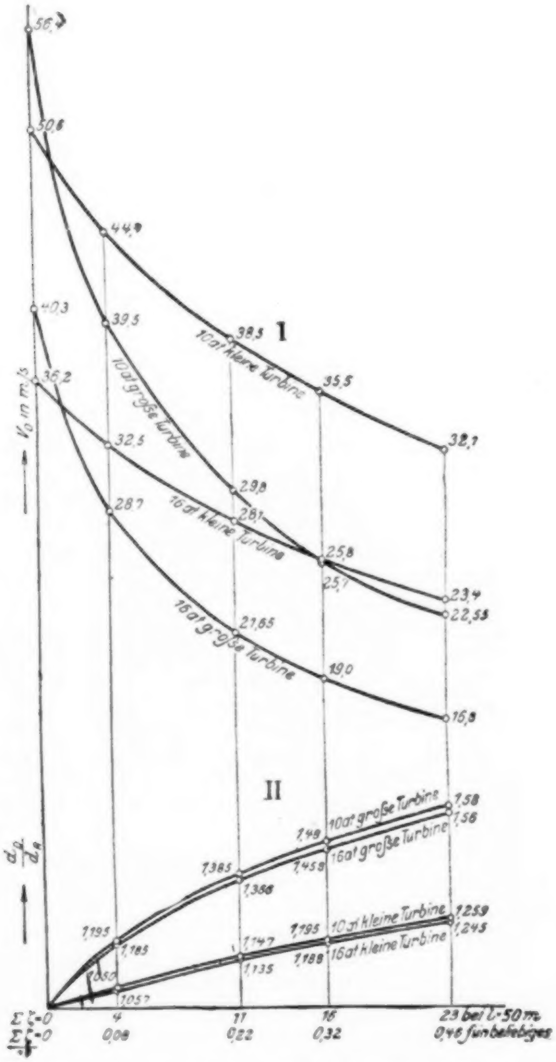

Fig. 3 I—Velocity v_D for the Smallest Steam Consumption as Function of Pressure p_a and Individual Resistances $\frac{\Sigma\zeta}{l}$ at the Temperature t_a = 350 Deg. Cent.

II—Increase of the Most Favorable Pipe Diameter d_D as a Result of Increase in Individual Resistances Represented by the Ratio $\frac{d_D}{d_R}$ in Functional Dependence Upon $\frac{\Sigma\zeta}{l}$

The author then proceeds to consider the question of costs under conditions prevailing in Germany during the first quarter of 1920. These values appear in Figs. 3 and 4 and they indicate the great influence which resistance in the valves has on the economic dimensions of piping or the velocity of steam flow. If we consider as a standard the most favorable case, namely Case 1, with two Koswa valves of low resistance to flow and no steam trap, it would appear that Case 3, in which ordinary valves are used, would require an increase of the diameters d_D and d_b (columns 7 and 9 of Table 1) by 23 per cent, corresponding to a reduction in the velocity of steam from 100 per cent to 64 per cent (columns 8 and 10). If, however, steam traps are provided which have a high resistance to flow (ζ = 7), the difference becomes much smaller, a comparison of Cases 2 and 4 showing only an increase of diameter from 115 per cent to 132 per cent (columns 7 and 9).

In general, it would appear that

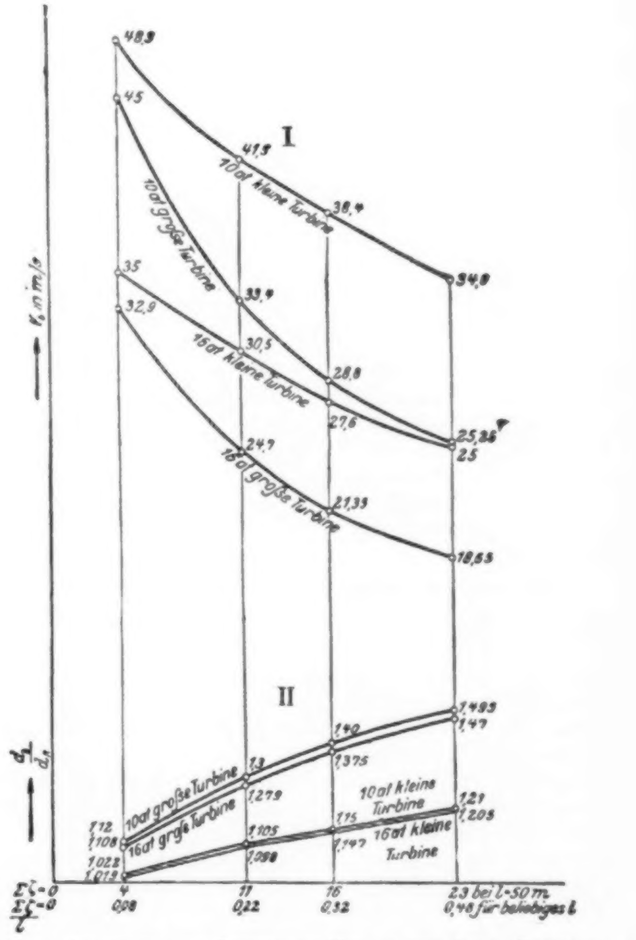

Fig. 4 I—Velocity v_b as Result of Use of the Most Economical Pipe Diameter d_b as a Function of Pressure p_a and Individual Resistances $\frac{\Sigma\zeta}{l}$ at Temperature t_a = 350 deg. cent.

II—Increase in the Most Economical Pipe Diameter d_b Produced by Increase in Individual Resistances Represented by the Ratio $\frac{d_b}{d_R}$ in Functional Dependence upon $\frac{\Sigma\zeta}{l}$

At kleine Turbine = atmospheres, small turbine; *at grosse Turbine* = atmospheres, large turbine; *Koswa-Ventile* = Koswa valve; *norm. Ventile* = ordinary valve; *ohne Wasserabsch.* = without steam trap; *mit Wasserabsch.* = with steam trap; *bei* = at; *für beliebiges l* = for any l.

Case 1. The sum of the individual resistance $\Sigma\zeta$ = 4. This arrangement contains two modern valves with low resistance to flow (ζ = 1) and there are a few bends in the piping. As an example of a modern valve the author mentions the Koswa, which is built by several concerns in Germany.

Case 2. $\Sigma\zeta$ = 11. Here there are two Koswa valves (ζ = 1), a few bends, and in addition a large steam trap (ζ = 7).

Case 3. ζ = 16. This arrangement comprises two ordinary valves offering a large resistance to flow (ζ = 7) and a few bends.

Case 4. $\Sigma\zeta$ = 23. In this case there are two ordinary valves (ζ = 7), a few bends, and a large steam trap (ζ = 7).

1 A reduction of the individual resistances in piping effected by replacing ordinary valves by Koswa valves is the more advantageous the lower are the other individual resistances in the installation; and that

2 Steam traps with their present construction and high resistances to flow are particularly unfavorable.

It is worth noticing that the economical velocities of steam are comparatively low, in any event lower than those usually assumed. At high pressures ($p_a \leq$ 16 atmos.) and with large turbines the most economical steam velocities are $v_b \leq$ 32.8 to 35 m. per sec. (107.62 to 114.82 ft. per sec.), and for the case of ordinary valves

TABLE 1 DIAMETER OF PIPING IN SUPERHEATED-STEAM PLANTS AND ECONOMICAL VELOCITY OF STEAM AS AFFECTED BY STEAM VALVES AND STEAM TRAPS

1	2	3	4	5	6	7	8	9	10	7a	8a	9a	10a
						Large Turbine, Steam Consumption G = 45,000 kg. per hr.				Small Turbine, Steam Consumption G = 5000 kg. per hr.			
Case	Valves: Number and kind	Valves: Resistance factor	Resistance factor of steam trap	Other resistances	$\Sigma\zeta$ Columns 3, 4, 5	d_D per cent	v_D m. per sec. = per cent	Most economical diameter d_b per cent	Most economical velocity v_b m. per sec. = per cent	d_D per cent	v_D m. per sec. = per cent	Most economical diameter d_b per cent	Most economical velocity v_b m. per sec. = per cent
	Initial Pressure p_a = 16 atmos. abs.												
1	2 Koswa valves	2 × 1	–	2	$\Sigma\zeta = 4$; $\frac{\Sigma\zeta}{l} = 0.08$	100	28.7 = 100	100	32.9 = 100	100	32.5 = 100	100	35 = 100
2	2 Koswa valves	2 × 1	7	2	$\Sigma\zeta = 4$; $\frac{\Sigma\zeta}{l} = 0.22$	115	21.65 = 75.5	115.2	24.7 = 75	107.5	28.1 = 86.5	108	30.5 = 87.3
3	2 Ordinary valves	2 × 7	–	2	$\Sigma\zeta = 16$; $\frac{\Sigma\zeta}{l} = 0.32$	123	13.0 = 66.4	124.1	21.35 = 64.6	112.5	25.8 = 79.5	113	27.6 = 29
4	2 Ordinary valves	2 × 7	7	2	$\Sigma\zeta = 23$; $\frac{\Sigma\zeta}{l} = 0.46$	131.6	16.6 = 57.8	133	18.65 = 56.6	118	23.4 = 72	118	25 = 71.5
	Initial Pressure p_a = 10 atmos. abs.												
1	2 Koswa valves	2 × 1	–	2	$\Sigma\zeta = 4$; $\frac{\Sigma\zeta}{l} = 0.08$	100	39.5 = 100	100	45 = 100	100	44.7 = 100	100	48.3 = 100
2	2 Koswa valves	2 × 1	7	2	$\Sigma\zeta = 11$; $\frac{\Sigma\zeta}{l} = 0.22$	116	29.8 = 75.5	116	33.4 = 74.3	108	38.5 = 86	108	41.5 = 86
3	2 Ordinary valves	2 × 7	–	2	$\Sigma\zeta = 16$; $\frac{\Sigma\zeta}{l} = 0.32$	124	25.7 = 65.1	125	28.8 = 64	113	35.5 = 79.5	112.8	38.4 = 79.5
4	2 Ordinary valves	2 × 7	7	2	$\Sigma\zeta = 23$; $\frac{\Sigma\zeta}{l} = 0.46$	132	22.5 = 52.5	133	25.3 = 56.2	119	32.1 = 71.7	118.5	34.6 = 71.6

with steam traps these reduce to $v_b \leq 18.65$ to 25 m. per sec. (61.16 to 82 ft. per sec.). Only the higher values are to be used for small turbines. The lower the initial steam pressure p_a the higher are the steam velocities, but even at $p_a = 10$ atmos., and in the most favorable case (Case 1), these velocities reach only the value $v_b = 45$ to 48.3 m. per sec. (147.63 to 158.45 ft. per sec.) or far below the values of 80 to 100 m. per sec. (262.4 to 328 ft. per sec.) recommended in technical literature. (*Der praktische Maschinen-Konstrukteur,* vol. 56, no. 15, Apr. 26, 1923, 3 pp., 2 figs., *t*)

Grjimailo's Hydraulic Theory of Boiler-Furnace Design

Modern Boiler Furnaces from the Point of View of Theory of Furnaces Based on the Laws of Hydraulics, W. E. Groume Grjimailo. Criticism of the design of the pulverized-coal-burning furnaces of the River Rouge plant of the Ford Motor Co. as described in a paper by H. D. Savage read before the American Iron and Steel Institute, May 27, 1921.

This furnace (Fig. 5) embodies, according to the author, a series of cumulative errors from the point of view of furnace theory based on the laws of hydraulics. These errors he points out in order to give an example of rational criticism of present-day constructions.

1 The flattened-out burner of the boiler furnace is very interesting. The atomization of the fuel is carried out by means of steam. In order not to lower the temperature of the combustion chamber it would be better to employ for this purpose compressed air at the same pressure as the steam in the boiler. The secondary air might be supplied to the burner preheated. The use of preheated air in pulverized-coal furnaces was adopted in Russia in 1918 and has given excellent satisfaction.

2 It is quite rational to direct the atomizing burner downward. Since the direction of the flame is inverted, the products of combustion because of their low specific gravity take an upward course in countercurrent to new quantities of the mixture of coal dust and air. This mixture ignites easily and the succession of reactions of combustion is not disturbed.

3 It is wrong, however, to locate the burner along the walls as this increases the depth of descent of the jet of incandescent gas and as a consequence increases the height of the combustion chamber. The author believes that in a rationally designed combustion chamber the jet of dust may be burned entirely out of contact with the walls of the combustion chamber. The quantity of ashes coming from pulverized coal and accumulating in the combustion chamber will be greater in the case where the flame jet does not reach the bottom of the chamber.

4 The construction of the combustion chamber of the River Rouge power plant is not rational. As the author has shown in his book The Flow of Gases in Furnaces (English translation, New York, 1923), the combustion chamber must represent a pocket of hot gases. The flame elements should stay below the combustion chamber for a period of at least 1½ sec., and it is only then that they may be allowed to pass through the ports in the hearth. The combustion chamber at the River Rouge plant is not designed to insure complete combustion of the dust, and it is to this fact of incorrect design that are due the excess of air used (15 to 30 per cent) and the high content of unconsumed carbon in the ashes (up to 9.52 per cent). It is obvious that in that furnace the flame reaches the interior of the boiler before the reactions of combustion have been completed, is cooled through contact with the cold tubes, and as a result of this the combustion cannot be completed with only a slight excess of air.

5 The flues of the River Rouge boiler are said by the author to be designed in an incorrect manner. By virtue of the theory of furnaces built in accordance with the laws of hydraulics, the streams which are cooled should be directed downward. It is only in such a case that one may expect that the cold boiler tubes would be uniformly enveloped by the gases of combustion and that the heat convection would be complete. The presence in the brickwork of a whole series of baffles tending to change the direction of the flames, indicates that the gases of combustion do not have the tendency to circulate along the tubes and that they are forced to do so merely by the chimney draft.

After this critical review of the River Rouge furnace, the author proceeds to present a design for the reconstruction of this furnace which would bring it in accord with the "hydraulic theory." This design is shown diagrammatically in Fig. 6.

1 The combustion chamber AA represents a "pocket" of hot gases. At the peak of the roof of this furnace is located the burner B giving the downward vertical jet.

2 Since the walls of the combustion chamber might suffer from the high temperature consequent on such a construction, passages C are provided in these walls and are utilized to preheat the secondary air supplied at a low pressure to the burner B.

3 The dimensions of the combustion chamber AA must be suited to the type of burner. The burner must be tested before the combustion chamber has been built, and the dimensions selected for the combustion chamber must be such as will enable it not only to contain the flame cone but also to provide space in which the products of combustion may rise freely along the walls of the combustion chamber and leave it through the ports D.

4 The ports D should be computed in accordance with the Yesmann's formula:

$$h = A^3 \sqrt{\frac{O^2}{B^2 t}}$$

5 The incandescent gases should rise to the chambers F_1 and F_2 where the boilers are located.

Contrary to the usual custom but in conformity with the hydraulic theory, the author would incline the boiler tubes toward the flues rather than toward the furnace. It is obvious, of course, that with the tubes thus inclined there is no need to provide baffles in order to force the incandescent gases to envelop the tubes and give up to them their heat.

6 With the arrangement described above we then have cold vertical tubes located in an atmosphere of stationary incandescent gases. Near the surface of the tubes there is a layer of products of combustion which will give up its heat to the tubes and will be cooled to the temperature of the latter.

As soon as the layer of gases in contact with the tubes is cooled

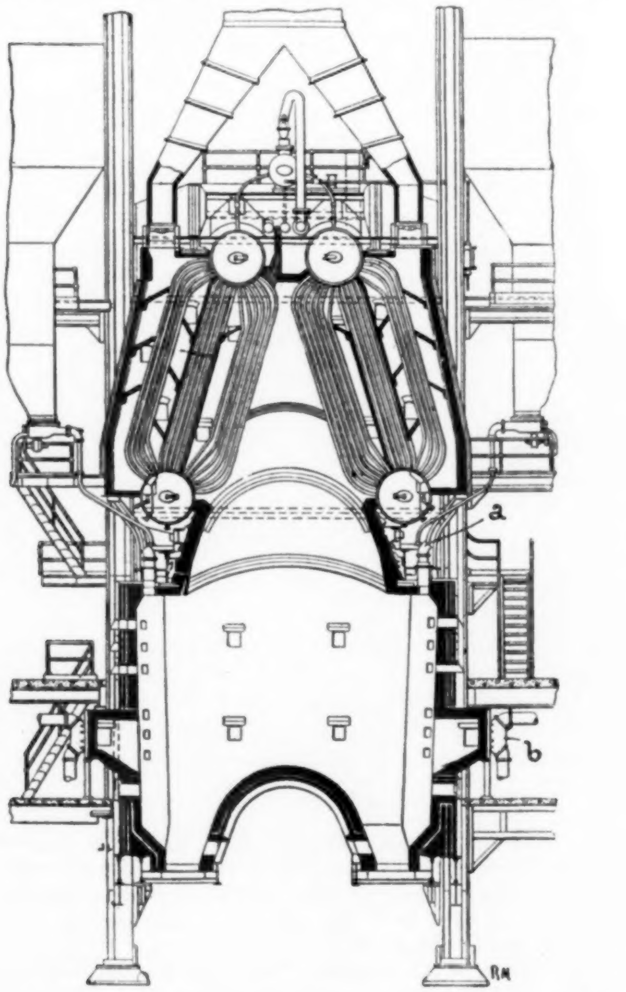

Fig. 5 Boiler Installation at the River Rouge Plant of the Ford Motor Co.
(a—Pulverized Coal; b—Gas Burner.)

down, it obviously cannot remain in equilibrium in an atmosphere of the lighter furnace gases. It begins to descend and a quantity of incandescent furnace gases comes to take its place. These new gases in their turn are cooled down and, becoming heavier, move downward along the tubes. In this manner, quite naturally and without the assistance of any baffles whatsoever, there is established in the confines of the boiler the following circulation of gases:

a The furnace gases rise toward the roof of the boiler chambers F_1 and F_2 through the ports D;

b Through coming in contact with the boiler tubes, these gases are cooled and then move downward;

c By placing the flue ports g_1 and g_2 near the bottom of the combustion chambers F_1 and F_2 and by giving the boilers a slight incline toward these ports, it is possible to secure an absolutely correct circulation from top to bottom in which the colder gases flow toward the flues without the employment of any baffles, without in any way interfering with their employment, without restricting the uniformity of this movement, and without disturbing the regularity of heat transmission from the gases to the boiler walls.

One may make use of the formula of vertical gas jets:

$$h = \frac{V^2}{2g} \times \frac{273 + ti}{tm - ti}$$

by introducing into it a correction coefficient. This coefficient

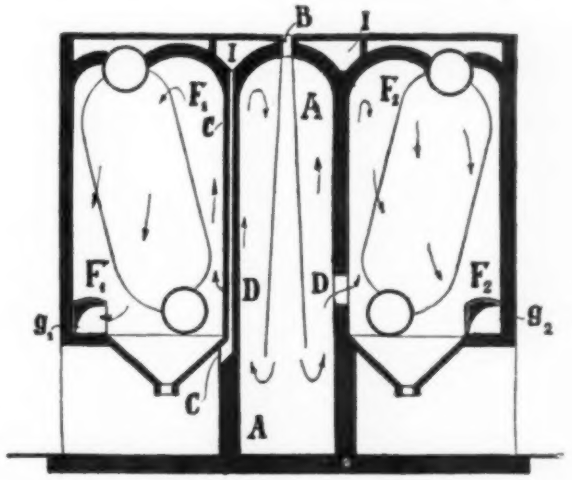

Fig. 6 Diagrammatic Design of the Installation Shown in Fig. 5, Bringing It in Conformance with the Author's Hydraulic Theory of Furnace Design

was found to be equal to 0.7 by the engineer Slessareff, who has made a special study of this subject at the Polytechnic School at Petrograd. With this value one is enabled to establish the formula for the velocity of circulation of gaseous streams along the boiler tubes, namely,

$$V = \sqrt{0.7 \frac{tm - ti}{273 + ti} 2gh}$$

Assuming that tm = 1100 deg. cent. and ti = 300 deg. cent.,

$$V = 0.64 \sqrt{2\, gh}$$

As in this case the length of the boiler tubes is 5.3 m. (17.4 ft.) the velocity of descent of the cold gas streams is found to be equal to

$$V = 0.64 \sqrt{2 \times 9.81 \times 5.3} = 6.5 \text{ m. per sec.}$$

It would appear, therefore, that the velocity of the small streams at the top near the walls of the main body of the boiler is close to zero. At the bottom toward the cylindrical bottom of the boiler this velocity becomes equal to 6.5 m. (21.3 ft.) per sec.

Knowing the quantity of gases of combustion reaching the boiler chamber, it becomes possible to calculate the thickness of the layer of gas surrounding each tube. According to the author's calculation it does not exceed 25 mm. (1 in.).

7 The water circulation in the boilers takes place in the ascending direction from the lower cylindrical drum toward the main upper boiler, i.e., opposite to the direction of the circulation of the hot gases. This creates exceedingly favorable conditions for the convection of heat.

8 In conclusion, the author discusses briefly the preheating of air. In the design of boiler under consideration the air is taken in through openings in the manholes provided for cleaning the boiler. It then rises through the vertical passages CC provided in the walls of the combustion chamber and finally reaches the collector passages II. Its pressure in the upper passages become

equal to that of the atmosphere so a blower may be dispensed with by selecting the proper type of burner. However, it is a more certain process to take the air from the passages *H* by means of a blower and thus deliver it to the pulverized-coal burners. The author believes the use of hot air would make it possible to burn coarse pulverized fuel and use equally well dry coals or those containing considerable moisture. (*Revue de Métallurgie*, vol. 20, no. 3, March, 1923, pp. 189–192, 2 figs., *t*)

Central Station Using Steam at 1200 Lb. Pressure

New Extra-High-Pressure Steam Station, I. E. Moultrop and Joseph Pope, Members A.S.M.E. Description of the Weymouth Fore River Station of the Edison Electric Company of Boston, of interest because it includes a boiler working at a pressure of 1200 lb. per sq. in.

Steam from this extra-high-pressure boiler will first pass through a turbine developing about 200 kw., whence it will be exhausted at 375 lb. pressure. It will then be reheated to 700 deg. fahr. and sent on the larger turbines.

Reheating of the steam is essential if the full benefit is to be obtained; without it the most economical top pressure seems to be 375 lb. The feedwater is to be heated by two-stage bleeding of the main units and by economizers. All the ordinary auxiliaries are to be driven by alternating current derived from a 2500-kva., 2300-volt alternator, direct coupled to the main generator shaft of each 30,000-kw. turbo set, which, with the 2500-kva. alternator, totals some 32,000 kw.

It is hoped that this combination of 1200-lb. and 375-lb. sets will yield a kilowatt-hour for 13,600 B.t.u.

The 1200-lb.-pressure boiler will, like the lower-pressure (375 lb.) boilers, have a heating surface, of 19,743 sq. ft. It will have its own economizer, superheater, and resuperheater. All boilers will be fired by underfeed stokers.

Now for the question of total heat and efficiency possible. In Fig. 7 curve No. 1 shows the total heat above 79 deg. fahr. in 1 lb. of steam at a uniform temperature of 700 deg. fahr., 79 deg. being the temperature corresponding to 1 in. absolute pressure. It will be noted that the total heat shows a decrease with increasing pressure.

Curve No. 2 shows the heat remaining in the steam after perfect adiabatic expansion from the stated initial conditions to a pressure of 1 in. abs. The vertical distance between this curve and curve No. 1 accordingly represents the B.t.u. per lb. of steam theoretically available for doing work.

Curve No. 3 is a plotting of the available heat as a percentage of the total heat shown by curve No. 1 and represents the efficiency of the Rankine cycle at varying pressures. Its upwardly convex curvature indicates how the rate of increase in theoretical efficiency diminishes with increasing pressure.

Curve No. 4 shows the best efficiency at present to be expected of turbo-generators in converting the available heat, as shown by curve No. 3, into useful electrical energy. In determining this curve the unit is credited with all heat recovered in the condensate by bleeding at two stages.

Curve No. 5 is the product of curves Nos. 3 and 4 and indicates, for the different pressures, the percentage of the total initial heat in the steam which would be actually converted into electrical energy or returned to the boiler in the condensate. It will be noted that this curve takes the shape of a dome with its highest point corresponding to a steam pressure of about 600 lb. abs.

If steam turbines could be constructed which would be equally efficient in transforming the available heat energy into useful work under all conditions of initial steam pressure, curve No. 3 would indicate that the overall thermal efficiency would increase with the pressure throughout the entire range considered. The most important factors which act to decrease the turbine efficiency at higher steam pressure are the increased gland and interstage leakage losses and, more particularly, the increased steam friction occasioned by the entrained water after the dewpoint has been reached. This lowered efficiency is particularly marked where the maximum permissible total temperature causes the higher pressures to be accompanied by diminished superheat, thus advancing the dewpoint to an earlier stage. The recognized method of meeting this difficulty, and thus permitting the superior possibilities of higher steam pressures to be realized, is to interrupt the expansion of the steam at some intermediate pressure and restore its temperature by reheating before the expansion is continued. This may be accomplished either by employing two independent turbines, one exhausting to the other through the reheater, or by returning the reheated steam to the lower stages of the same machine from which it was extracted. The design of the Weymouth station makes provision for employing the former of these two methods, using a maximum pressure of 1200 lb.

The high-pressure boilers will have tubes 2 in. in ouside diameter and 15 ft. long. The tubes will be arranged in ttwo banks with sufficient space between for the superheater and reheater. The drum will be a hollow steel forging 48 in. in outside diameter with walls 4 in. thick. In order to maintain suitable drum strength the tubes and nipples, which commonly enter the drum in lines parallel with its axis, are turned in pairs through an angle of 90 deg., so that the two enter the drum on a common circumference. Make-up water is to be provided by evaporators, and the whole supply will be deaerated.

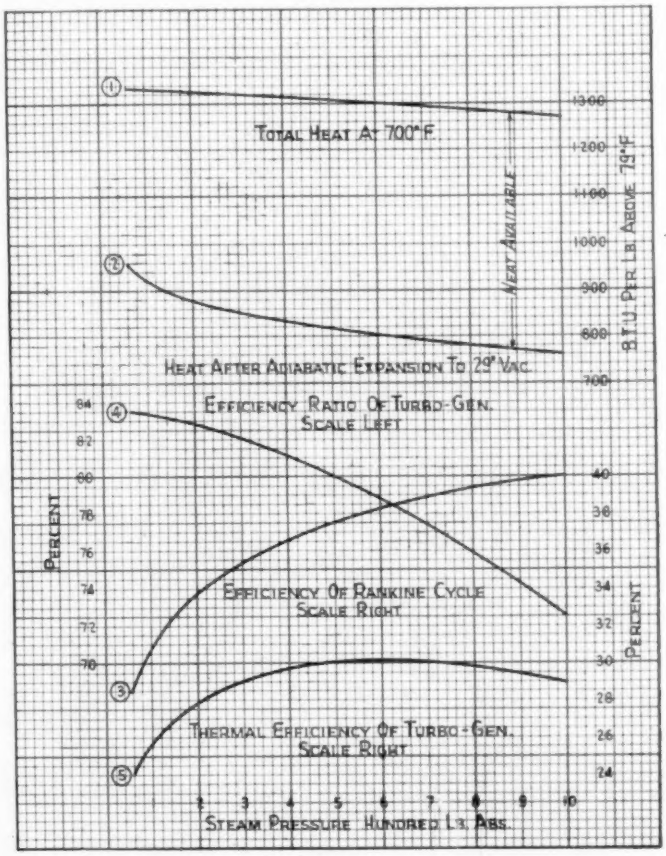

Fig. 7 Effect of Steam Pressure on Turbine Thermal Efficiency

An article in the *Electrical Times* (vol. 63, no. 1654, June 28, 1923, pp. 677–679), in commenting upon this paper, states as follows:

"So here we see that the steam generated at 1200 lb. and used at 1000 lb. only means an extra $2^1/_2$ per cent in efficiency, which is not exactly a sumptuous gain, and must be considered in its commercial relation to the extra cost of plant. But we must by no means thrust it aside and leave it at that; there are too many hard-headed experimenters and business firms at work on it to allow us for one moment to regard this as a chimera. Dr. Ferranti believes that we are in view of an overall thermal efficiency of 30 per cent. And in saying this he has in mind only steam boilers and turbines; he would no doubt allow that other combinations are conceivable." (Paper presented at the 1922 Spring Meeting of The American Institute of Electrical Engineers, abstracted through *The Electrical Times*, vol. 63, no. 1654, June 28, 1923, pp. 677–679, 3 figs., *d*)

A Combined Cylindrical and Water-Tube Boiler

The Hudson Boiler. Description of a boiler which is a combination of the cylindrical and water-tube. It is made in two distinct types. For large evaporators the cylindrical element consists of a short two-flued boiler of the Lancashire type, while for smaller requirements it is of the single-flued or Cornish type. In either case the cylindrical element is flanked on each side with the nest of water tubes set low down in the front and rising toward the back end of the boiler. The bottom header of each nest of tubes is connected by a mild-steel pipe of large capacity to the drum at the fore end of the cylindrical elements. This simple means of combining two distinct types of boilers in one unit results in a very powerful steam generator, which, while retaining the simplicity of the cylindrical boiler, gives a very much higher efficiency.

The passage of the gases through the boiler is by means of the internal furnace flue until they reach the back end of the cylindrical element. From this point they pass through a port into side flues and sweep along and over the water tubes and also along the side of the cylindrical element, after which they pass into the main flue under the boiler. The position of the tubes is therefore such that they are not exposed to intense local heat as the gases do not come into contact with them until after they have passed through the length of the internal flues of the cylindrical element (Fig. 8). The circulation of the water in the boiler is obtained by feeding the water through the front end. The cold water flows to the bottom of the cylindrical element and then passes through the connections into the bottom drums of the water-tube elements, passing up the tubes where it is met by the gases flowing in the opposite direction, the steam formed making its way up the inclined tubes to the back header and then into the steam space of the cylindrical element. Because of this there is a definite circulation of water in the cylindrical element of the boiler, which insures uniformity of temperature.

The results given in Table 2 of an evaporative test would indicate that with this type of boiler the economizer can be dispensed with. (*The Iron and Coal Trades Review*, vol. 107, no. 2889, July 13, 1923, p. 40, 1 fig., *d*)

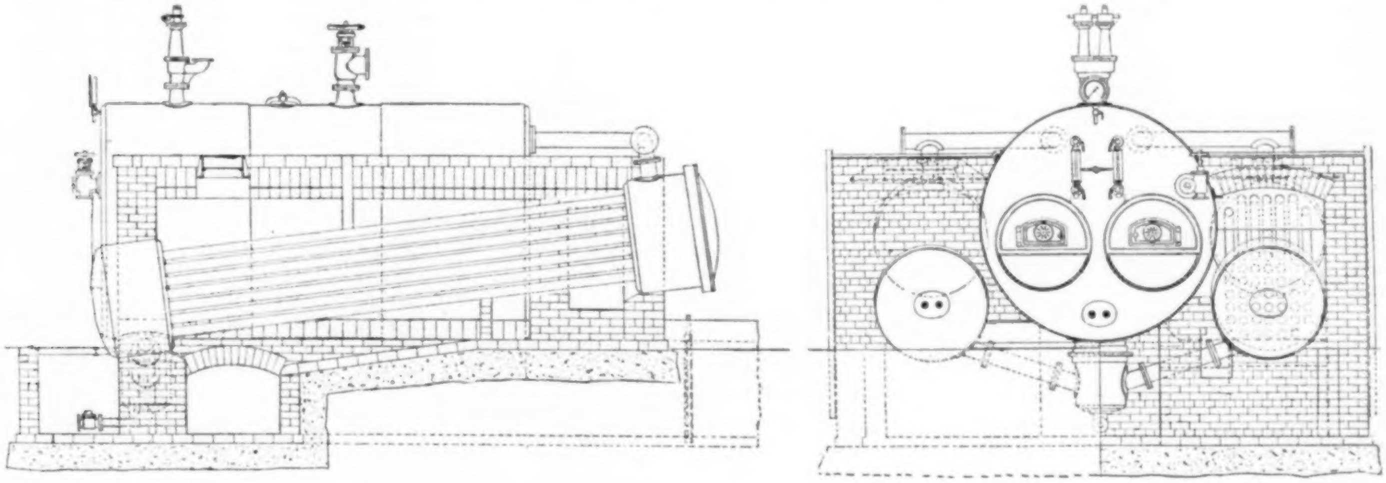

Fig. 8 Hudson Combined Cylindrical and Water-Tube Boiler

TABLE 2 EVAPORATIVE TEST ON TWO HUDSON PATENT CYLINDRICAL AND WATER-TUBE BOILERS AT THE WORKS OF THE ROSE PATENT FUEL COMPANY, LTD., SWANSEA

Heating surface of each boiler, sq. ft.	2470
Grate area of each boiler, sq. ft.	45.5
Ratio of heating surface to grate area	54 to 1
Duration of test, hr.	5
Boiler pressure (gage), lb. per sq. in.	155.5
Boiler pressure (absolute), lb. per sq. in.	170.0
Temperature of feedwater to boiler, deg. fahr.	43
Temperature of steam leaving superheater, deg. fahr.	590
Total weight of feedwater during test, lb.	95,550
Factor of equivalent evaporation (boiler only)	1.224
Factor of equivalent evaporation (including superheater)	1.347
Weight of feedwater per boiler per hour, lb.	9555
Equivalent evaporation from and at 212 deg. fahr., lb.	12,870
Fuel used during test	Rose patent fuel briquets
Heating value of fuel per lb., B.t.u.	13,568
Total weight of fuel burned, long tons	5.1
Weight of fuel burned per boiler per hour, lb.	1154
Water evaporated per lb. of fuel burned, lb.	8.28
Equivalent evaporation per lb. of fuel from and at 212 deg. fahr., lb.	11.15
Temperature of escaping gases taken at chimney, deg. fahr.	473
Draft in inches of water,	0.92
Percentage of ash and clinker to total weight of fuel used during test	8.84
Boiler efficiency, per cent	80

Steam Accumulators, M. Emanaud. General considerations on the subject, together with descriptions of the Halpin, Morison, Rateau, and Ruths accumulators, and a bibliography on the subject. The various types are illustrated. The Ruths accumulator was described in Mechanical Engineering, vol. 44, no. 5, May, 1922, pp. 323–324. The other accumulators are well known.

The following comparison of types may be of interest. The apparatus of the gas-holder type can be charged most rapidly, as there is no necessity in this apparatus for mixing to obtain a uniform temperature. That is because an absence of uniform temperature in this apparatus will have no effect on its ability to absorb steam, which is the case with all apparatus in which the steam is condensed in the water. This sort of apparatus also maintains a steadier pressure and hence has less influence on the machinery supplied by it with steam.

On the other hand, these bell accumulators are more bulky than the water type, because the uncondensed steam has a much greater volume in comparison to the steam when condensed in water. The advantage obtained here, however, is not so much as one might at first believe, because the water-reservoir type of accumulator necessitates the storage of a large volume of water which is to be transformed into steam during the accumulator's discharge.

Supervision is much easier and heat insulation is much less expensive in the water-reservoir type of apparatus than in the gas-holder type, because in the first type there are no moving parts. The latter type of accumulator, when well designed to insure a uniform temperature and to avoid violent ebullition, is a machine of definite functioning qualities which permits remote control and needs a minimum operating force.

The degree of saturation of the steam supplied by accumulators depends not only on more or less regular ebullition and release of steam in the apparatus, but also on the fall in pressure obtained in the reducing valve at the outlet. (*Chemical and Metallurgical Engineering*, vol. 29, no. 4, July 23, 1923, pp. 149–152, 10 figs., *dc*)

RAILROAD ENGINEERING

Transverse Fissures in Steel Rails

A Study of Transverse Fissures in Steel Rails, James E. Howard. The article here abstracted is itself an abstract from a report made to the Interstate Commerce Commission by the author who is engineer-physicist of that body.

A transverse fissure as a specific type of fracture was first recognized in a report to the Interstate Commerce Commission dealing with an accident which occurred in 1911. The term applies to a type of fracture which has its origin in the interior of the head of a rail and which progressively enlarges from a definite nucleus.

The plane of rupture is here crosswise the length of the rail and substantially perpendicular to its axis. Transverse fissures have an interior origin, because the metal immediately below the running surface of the head is in a state of compression due to the cold-rolling effects of the wheels.

The number of transverse fissures considered in this report exceeds 8000, this being only a partial list of the total number of fissures which are a matter of record. They occurred in rails coming from every rail mill in the country, and in numbers predominated on trunk lines of high speed, heavy equipment, and congested traffic. It appears that transverse fissures in larger numbers on the gage side of the head of the rail than over the web or in the outer half of the head.

Transverse fissures being of progressive formation, their final stage of development may occur at any time. The length of time required for incipient fissures to make their presence known depends upon the amount and character of traffic carried by the rails. It does not appear that the appearance or absence of transverse fissures depends on the part of the ingot that the rail comes from.

A somewhat different feature is presented in the consideration of the ages of rails with respect to their ingot positions over that of their numerical relations. Rails which fractured in largest numbers during the first few years in the track came from those parts of the ingot which are generally conceded to be the best. Rails from segregated parts were fewer in number. These results cast a doubt upon the validity of connecting the formation of transverse fissures with the segregated parts of the ingot.

The average ages of transverse fissures on different railroads in the main reflect traffic conditions. Weights of equipment, gross tonnage, and speeds are the prominent features which characterize the conditions on those roads where maximum numbers and minimum ages of fissured rails appear.

While there is no known reason why bessemer and open-hearth rails should not behave substantially alike in respect to the formation of this kind of fracture, their comparative absence in bessemer rails has been noted.

Transverse fissures have also been produced experimentally by subjecting rails to treatment analogous to the cold-rolling action of wheels. This result was accomplished by repeated alternate overstraining of the rail longitudinally. Half-length rails were used, applying gagging blows at short intervals along the length of the head, then reversing the bend and gagging the base in the same manner. This alteration of reversed bending was continued until ultimate rupture ensued.

The position of the interior fissure was found controllable at will. Gagging the rail in upright position yielded a transverse fissure centrally over the web; inclining the rail to the right or to the left and applying the gagging blows in an oblique direction yielded transverse fissures located in the right or left side of the head, whichever way the rail was canted.

Broadly considered, three features constitute the rail problem: (1) Girder strength; (2) abrasive resistance to the action of wheels; (3) cold-rolling effect of wheels on the head of the rail. If the third feature was eliminated there would be no rail problem, since the requirements of the first and second can be met without difficulty.

The most obvious deduction to be made from this compilation of data on the display of transverse fissures is the apparent close approach to the limit of endurance experienced by rails under the conditions of service which now prevail on the trunk lines of the country. The prevalence of transverse fissures reached a degree of magnitude some time ago, when serious and concerted action should have been taken to study the influences which affect the state of the metal of the rail in the upper part of the head, upon which rests the responsibility for the formation of transverse fissures. The ideal manner of advancing this subject would be through the coöperation of the trunk-line railroads and the steel mills. (*Railway Age*, vol. 75, no. 5, Aug. 4, 1923, pp. 210–212, *g*)

SPECIAL PROCESSES

Drying Equipment in an Artificial-Leather Plant

CHEMICAL ENGINEERING IN THE PRODUCTION OF COATED FABRICS, Sidney D. Kirkpatrick. Description of the manufacture of artificial leather and rubberized cloth at the plant of the Duratex Corporation, Newark, N. J. Of particular interest is the way in which the problem of air drying has been solved.

This drying equipment is an especially interesting application of air drying under rather unusual conditions. It is necessary to provide facilities for drying the base coating as rapidly as possible, and, at the same time, to remove the solvent vapors effectively, in order to keep explosion and fire hazards at a minimum. The system was designed and installed by the Carrier Engineering Corporation and makes use of the ejector principle for efficient circulation of the air. As may be seen from the plan and elevation shown in Fig. 9, it is designed according to well-known countercurrent principles. The air is delivered from the ejector nozzles at a velocity of approximately 1000 ft. per min., and passes over the driest cloth as it is on its way out of the drying chamber. In counter-direction the air then passes around the entire path covered by the cloth and is finally exhausted at an outlet directly beneath the coating head of the machine. The air current divides at the base of the fan and a part

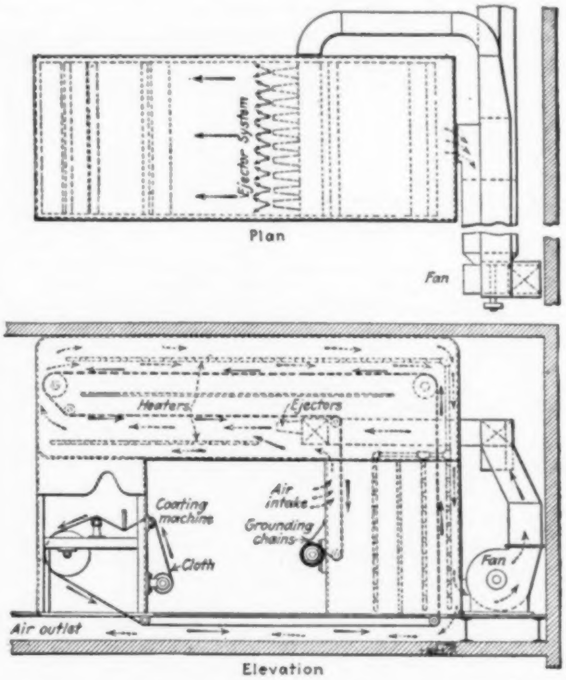

FIG. 9 PLAN AND ELEVATION FOR DRYING EQUIPMENT FOR PYROXYLIN COATING MACHINES

of the heated air is drawn into the fan to be recirculated directly by the ejector nozzles.

The apparatus handles about 2500 cu. ft. of air per min. for each of the coating machines. The temperature is maintained at approximately 175 deg. fahr. depending upon the amount of air handled and how vigorously it is circulated. The drying chambers over the machines are connected with an exhaust system which removes a sufficient quantity of the fume-laden air, to prevent an explosive concentration. At the present time no provision is made for solvent recovery, although the drying and ventilating system is so designed that an installation might be made with a minimum of expense and inconvenience. (*Chemical and Metallurgical Engineering*, vol. 28, no. 23, June 11, 1923, pp. 1017–1023, 17 figs., *d*)

THE FAUSER SYNTHETIC AMMONIA PROCESS. In this process ammonia is synthetized and then oxidized to nitric acid to produce ammonium nitrate.

The method used in the new process does not materially differ in principle from those of Haber and Claude. The original features of the Fauser process are as follows:

1 The direct introduction of the water for the absorption of the ammonia by an induction pipe on the compressor, which lubricates the latter, is a considerable improvement, as the high-pressure pumps used in other processes may be dispensed with.

2 The condensing column, common to all methods and used to separate the lubricant introduced by the compressors, is used in this case to separate and absorb the ammonia.

3 A scientific system of heat recovery from the gases leaving the reaction chamber gives a marked economy in the fuel required to separate the ammonia from the aqueous solutions.

The outstanding feature of the new process is the way in which all waste is collected and utilized; the expensive liquid-air plant for obtaining the nitrogen gas required in the ammonia synthesis is eliminated, and the nitrogen used is obtained entirely from the residual gas left in the process of oxidizing the ammonia by air. The process as a whole forms an apparently perfect closed chain in which the electric power supplied converts the raw materials, air and water, into nitric acid or nitrates without any useless by-products.

The working pressure is slightly higher than in the Haber process (300 atmos. instead of 200), which appears to allow the liquefaction of the ammonia in the anhydrous state without difficulty. The uncondensed portion is absorbed in water under pressure, and afterward obtained by means of an ingenious system of recovery and stored in a gasholder. The layout of the plant also contains other interesting features making for economy both in the operations with liquid ammonia and with the nitric acid. (*The Chemical Age*, vol. 9, no. 213, July 14, 1923, pp. 28–30, 3 figs., *d*)

The Use of Oxygen or Oxygenated Air in Metallurgical and Allied Processes, F. W. Davis. In view of the many recent developments in oxygen manufacture, and considering the increasing cost and decreasing quality of our raw materials, the Bureau of Mines, Department of the Interior, appointed an Advisory Committee to study the problem of the application of oxygen or oxygenated air to metallurgical and allied processes. M. H. Roberts, vice president of the Franklin Railway Supply and consulting engineer of the Bureau of Mines, is chairman of the Committee.

This committee has made a thorough survey of the existing processes for the manufacture of 99 per cent oxygen. The conclusions reached by this survey are that the comparatively small demand for the product has prevented the installation of large units suitable for metallurgical processes, with corresponding economies, and by far the greater proportion of the present cost of oxygen represents the cost of transportation, storage, and service. Large oxygen-manufacturing plants can be built to serve metallurgical purposes directly, which will be capable of delivering oxygen at a cost not to exceed $3 per gross ton. In other words, the Committee finds that the oxygen industry is now able to make plants for supplying large quantities of oxygen to metallurgical industries at low cost.

The Committee has made studies of the possible application of oxygen to ferrous metallurgy in general, to the metallurgy of zinc, to the manufacture of fuel gas, and for some miscellaneous industrial uses. The findings of the Committee on these theoretical studies are of such a revolutionary character that the members feel the strong advisability of conducting experimental work to verify the truth thereof, as well as to make changes in furnace design and processes in order to take full advantage of the probable benefits to be gained.

The results of these studies indicate that not only will the use of oxygen decrease materially the cost of present metallurgical processes, but that it will make available for use large quantities of low-grade ore and fuel which is now considered worthless. (*Reports of Investigations, Bureau of Mines*, Serial no. 2502, July, 1923, *ep*)

Rolling Steel and Non-Ferrous Rings. Description of a process of making rolled rings for gear blanks and for bearing and spinning blanks as used by the Weldless Rolled Ring Co., Cleveland.

The process of making rolled rings includes two main steps. The first is forging a hollow blank smaller than the desired ring from round or square bar stock by the usual upsetting process on a 5-in. National flange machine. (Blanks for rings weighing from 20 to 75 lb. are forged under a drop hammer or power press.) After the blank is formed it is placed on the rolling machine and rolled out, the wall thickness being decreased and the diameter increased until a ring is formed of the desired size and shape.

Among the advantages claimed for the rolled rings are that they can be rolled close to size and that sections can be rolled that cannot be drop-forged. Thus the periphery and inside can be made in such forms as full channel sections or with grooves. (*The Iron Age*, vol. 112, no. 4, July 26, 1923, pp. 204–206, 7 figs., *d*)

TESTING AND MEASUREMENTS

Direct Determination of Dewpoints of Gasoline-Air Mixtures. A method of determining directly the dewpoints of gasoline-air mixtures in the proportions required for use in internal-combustion engines has been devised by W. A. Gruse and was presented to the division of petroleum chemistry of the American Chemical Society in a paper read before that society at New Haven, Conn., on April 5, 1923. It is based on a belief in the fundamental significance of the dewpoint of a gasoline-air mixture and consists of blowing a fuel mixture of known composition against an internally cooled metallic mirror and observing the temperature at which dew is formed.

A detailed description was given of the apparatus used in making the determination and the results obtained were compared with those secured by R. E. Wilson and D. P. Barnard, 4th, by their method of equilibrium mixtures in tests previously reported by them. The distillation curves of three commercial fuels bought in the open market at Pittsburgh were studied, their dewpoints were investigated, and the effects of adding 1 and 2 per cent of kerosene were observed with a view to determining the sensitiveness of the dewpoint in the presence of small amounts of heavy ends. Increases of from 4 to 6 deg. in the temperature at which dew formed were noted with practically all of these fuels.

A direct determination of the dewpoint of samples of the same fuels used and offered for test by Wilson and Barnard showed that their figures are approximately 20 deg. lower than those determined directly and that the change in the dewpoint corresponding to a change from a 12-to-1 to a 15-to-1 mixture is of the order of 7 or 8 deg. when measured directly, whereas Wilson and Barnard in their tests previously referred to found a uniform variation of approximately 4 or 5 deg. for a number of different fuels.

A comparison of the figures for a second group of fuels shows that the direct determination gives dewpoints that are higher in all cases than those arrived at by the equilibrium mixture. (*a*) The apparatus can be constructed in an ordinary laboratory and machine shop; (*b*) with a little practice the dewpoints can be read with fair accuracy and reproducibility; (*c*) it is believed to be sufficiently direct to be free from large errors; and (*d*) it applies to volatile fuels of any nature. It is offered tentatively as suitable for the direct determination of the "effective" volatility of motor fuel with the idea that it may be useful in studying specifications and blending operations and for the control of other methods of evaluation. (*The Journal of the Society of Automotive Engineers*, vol. 13, no. 2, August, 1923, p. 170, *ep*)

An Experimental Sensitive Balance. A balance devised by Hans Peterson is said to be capable of weighing to a sensitiveness of $^1/_{300,000,000}$th part of a grain. The beam of the balance is a small piece of quartz measuring less than 2 in. in length and weighing about a grain only. What would correspond to the pans in an ordinary pair of delicate scales are suspended from quartz threads a thousandth of a millimeter (one twenty-five-thousandth of an inch) in diameter.

The actual weighing is done by measuring the vibrations of the balance by means of a spot of light thrown upon a scale, which shows the actual movement of the balance enormously magnified.

Such refined weighing has to be done in a vacuum, and the instrument is mounted in a container from which the air can be exhausted before the actual work commences.

The balance itself weighs about 3 grains and is sensitive to the ten-millionth part of a milligram. (*American Journal of Pharmacy*, abstracted through *Merck's Report*, vol. 32, July, 1923, p. 96, *d*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general, *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Test Code for Locomotives

Preliminary Draft of Code No. 15 in the Series of Nineteen Being Formulated by the A.S.M.E. Committee on Power Test Codes

THE revision of the A.S.M.E. Power Test Codes of 1915 which was begun by the present Committee is now progressing rapidly. Below is reproduced the Test Code for Locomotives. The Individual Committee which developed this Code is headed by Prof. J. M. Snodgrass as Chairman and consists of Messrs. G. M. Basford, W. F. Kiesel, Jr., G. E. Rhoads, E. C. Schmidt, M. Toltz and C. D. Young.

The Committee and the Society will welcome suggestions for corrections to and modifications of this draft of its Code from those who are especially interested in the testing of locomotives. These comments should be addressed to the Chairman of the Committee, in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

Introduction

1 Locomotive tests are of two leading kinds, laboratory tests and road tests. The former are made in a locomotive laboratory under conditions quite similar to those of a stationary power plant in which the power is absorbed by a brake. The latter are made under conditions of service on the road, the locomotive hauling a train of cars. The rules for conducting tests of steam locomotives are therefore divided into two parts: a code for laboratory tests and a code for road tests.

2 The locomotive being a complete steam plant in itself, embracing boiler, engine, and certain auxiliaries, a locomotive test will in general be comparable with the test of a stationary plant embracing somewhat similar equipment. Where locomotive tests include detailed tests of auxiliary equipment, those portions of the A.S.M.E. test codes applicable to the particular auxiliary apparatus under test should be employed in so far as may be practicable in testing such auxiliary apparatus.

3 Where locomotive tests are made with some object in view which is different from the objects specifically covered by these codes, it is expected that the codes presented may constitute the basis for determining methods to be adopted, the data to be taken, et cetera. The codes are prepared for the test of a two-cylinder simple locomotive using superheated steam. When the locomotive tested is of a different kind from that for which the code is prepared, modifications may be required in the test procedure or in the reporting of the data and results. Where such modification of the code is necessary, it should be made with the view to reporting results which may be of the greatest possible value for comparative purposes with other test results reported under the code or under some slight modification thereof. In order that locomotive test data and test results may have the greatest possible value, particularly for comparison with more or less similar test data and results, it is desirable that the data taken be fairly complete as to the items indicated in the code here submitted, and that in the making of tests for special objects or with special locomotives the methods indicated in the codes as desirable be adopted in so far as conditions will permit. Where a fuel is used other than coal, for which the code is specifically prepared, modifications of the code may become necessary and should be governed by the same considerations concerning completeness and uniformity of data, and the desirability of reporting results that may be valuable for purpose of comparison.

Test Code for Laboratory Tests

Objects of Test

4 The object of a laboratory test as covered by this code is the determination of the coal and steam consumption per unit of power when the locomotive is operated under fixed conditions.

5 If the object of the test differs from that for which the code is specifically prepared the particular object should be determined and recorded in accordance with the suggestions of Pars. 1, 2, and 3 of the General Instructions, and the entire conduct of the test should be in accord with the object in view.

Measurements

6 The principal determinations which must be made in a test of a locomotive are:

(a) The engine and driving-wheel dimensions for horsepower calculations
(b) The leading boiler dimensions, such as grate surface, heating surface, and boiler volume, which enter into calculations involving coal and water consumption
(c) The operating conditions, such as throttle and reverse-lever positions, which define test conditions
(d) The speed
(e) The indicator diagrams for the determination of horsepower and engine conditions
(f) The temperature of laboratory, feedwater, superheated steam, in firebox, and in front end
(g) The barometric pressure
(h) The relative humidity of the atmosphere
(i) The boiler pressure
(j) The draft in ashpan, firebox, and front end
(k) The quality of the steam in the dome
(l) The weight of the feedwater and the weight of water and steam lost or used through leaks, auxiliary apparatus, etc.
(m) The weight of the coal fired
(n) The weight of the ash
(o) The weight of the cinders
(p) The chemical analysis and calorific determinations of the coal, ash, and cinders
(q) The composition of the front-end gases
(r) The blackness of the smoke
(s) The drawbar pull
(t) The dimensions and determinations that may be required in connection with such auxiliary apparatus as may constitute a part of the locomotive undergoing test.

Instruments and Apparatus

7 For laboratory tests it is assumed that a testing plant is available where the driving wheels can be mounted upon the supporting wheels of a friction-brake apparatus for suitably disposing of the power. The essential parts of the test plant which must be considered as necessary apparatus are:

(a) The mounting or revolving wheels upon which the drivers run while the locomotive is in operation
(b) The brake apparatus by which the work of the locomotive is absorbed and dissipated
(c) The dynamometer for the determination of the work done or the power developed.

A fourth piece of apparatus which, on account of its size, in order that it function properly, must generally be considered as a portion of a testing plant, is

(d) The cinder separator and collector.

8 Other apparatus and instruments required for a laboratory test are:

(e) Water-weighing apparatus
(f) Weighing apparatus for coal, ash, and cinders
(g) Graduated scale attached to the water glass
(h) Pressure gages, draft gages, thermometers, and pyrometers
(i) Barometer and hygrometer
(j) Speed-measuring apparatus
(k) Steam-engine indicators with indicator rigging or reducing motion
(l) Steam-sampling apparatus and steam calorimeter
(m) Gas-sampling and gas-analysis apparatus
(n) Coal-, ash-, and cinder-sampling apparatus
(o) Fuel calorimeter
(p) Smoke charts or other apparatus for the purpose of making smoke-density determinations.

In addition to the above it is necessary or desirable to have planimeters, micrometers, scales, calculating instruments, etc.

9 The laboratory test described in the Locomotive Code cannot readily be made unless a testing laboratory is available where the locomotive may be sent, and where this work may be carried on. Such a laboratory is too expensive to be constructed for the purpose of ascertaining the performance of an individual locomotive. How to arrange and install a laboratory testing plant seems therefore a matter for independent consideration.

10 At the present time the following universities have loco-

motive-testing laboratories: Purdue University, Lafayette, Ind.; University of Illinois, Urbana, Ill.; and Iowa State University, Ames, Iowa. Under certain arrangements locomotives may be sent to these laboratories for test purposes. Information concerning the design and operation of these laboratories has been published in reports concerning them and their work. The Pennsylvania Railroad Company maintains and operates a locomotive-testing laboratory at Altoona, Pa.

11 In 1904 the Pennsylvania Railroad Company carried on an elaborate series of locomotive-laboratory tests at the Louisiana Purchase Exposition, St. Louis, Mo. A description of the plant there installed, and of the tests made upon it, may be found in a volume published in 1905 by that company entitled, Locomotive Tests and Exhibits. This plant and the tests referred to were planned under counsel of an advisory board, three of whom were members of The American Society of Mechanical Engineers.

12 Directions regarding the use, the calibration, and the accuracy of the instruments mentioned in this section are given in Pars. ——— and ——— of the code on Instruments and Apparatus.

Preparations

13 Pars. 1 to 15, inclusive, of the General Instructions should be read and carefully studied.

13a Dimensions. General directions concerning dimensions are given in Pars. 4, 5, and 6 of the General Instructions, and Table 1 presents a form for recording the usual dimensions to be taken. In general the dimensions recorded should be determined by actual measurements of the locomotive undergoing test. The cylinder clearance may be determined approximately from working drawings of the locomotive. When this is done the dimensions used should be checked by actual measurements. When practicable the clearance should be determined by the water-measurement method. The water-measurement method of determining clearance is described in Par. 50 of the Rules for Conducting Tests of Reciprocating Steam Engines.

The dimensions of certain portions of the locomotive should be recorded, usually by reference to drawings or prints that may become a part of the recorded data. Such records, though varying somewhat with the nature and purpose of the test and the equipment tested, are indicated by and in general should include the following:

I The front-end-arrangement dimensions
II The location of the throttle valve and the actual lift of throttle valve in relation to throttle-lever position
III The reverse-lever arrangement and quadrant marking
IV The connection between the boiler and the gage glass which is used in determining height of water in the boiler.

13b Leakage. In general all leakage of water, steam, or air should be eliminated or reduced to a minimum. Where leakage is considered unavoidable or permitted for other reasons, its amount or effect should be determined with the greatest exactness possible. The principal ways in which serious loss or error through leakage may occur are:

I Blows past the piston and valve packings
II Leaky flues, leaks at mud ring or at boiler seams
III Leaks into the front end from superheater or other steam-pipe joints
IV Leaking throttle
V Air leaks into the front end.

Somewhat elaborate methods of determing leakage have been described in certain of the test codes such as those relating to Complete Steam Power Plants and Steam Engines which may be adapted to a greater or less extent in connection with the determination of leakage during locomotive tests. When the leakage may be considerable during a locomotive test and extreme accuracy is aimed at, the methods of determining leakage described in the various codes which are concerned with apparatus similar to that of the steam locomotive should be studied and made use of, in so far as may be practicable. For the most part leakage determinations in connections with locomotive tests can only be considered as somewhat roughly approximate and, where test conditions do not require otherwise, the effort should be made to eliminate leakage rather than to measure it accurately.

13c Physical Conditions. Attention to wear or variations from what are considered usual conditions as to dimensions should be given, particularly in regard to such items as the following:

I Preferably all driving wheels should be the same diameter and should be of standard contour. The exact method of taping the tires should be recorded
II Each pair of driving wheels should be checked to see that they are correctly quartered for the crankpin
III The frames should be tested to see that they line with the cylinders
IV The stack and draft pipe should be lined to determine that they are properly erected with reference to the exhaust nozzle
V Grates should be examined with regard to wear or broken parts.

13d Service. Records should be made concerning the previous performance of the locomotive, particularly of unusual service to which it may have been subjected or unusual attention which it may have received. The following indicate items for consideration:

I Miles run and nature of service since built or since last shopping for general repairs
II Nature of recent light repairs
III Methods of lubrication and kinds of lubricant used
IV Condition of the tubes and boiler as a whole regarding scale and sediment
V Information concerning the kind of water used during the tests and immediately prior thereto.
VI Valve gears should be checked that their performance may be known and compared with that of the standard for the locomotive.

13e Installation of the Testing Appliances Install and calibrate the testing appliances in accordance with Pars. 9 to 12 of the General Instructions and in accordance with the Main Code section on Instruments and Apparatus. The location of apparatus and instruments and their use in locomotive testing should in general be the same as in similar tests of stationary apparatus unless there is a good reason, on account of lack of space or other considerations, for variations from the usual practice. Reference may be made to the boiler and engine codes or to such other A.S.M.E. codes as are concerned with apparatus similar to that tested during a locomotive test. A suitable signal arrangement should be installed so that observations may be properly timed and that, where desirable, simultaneous observations may be made.

Two water-weighing tanks of about 1500 lb. capacity each, placed upon platform scales of about 2500 lb. capacity, and one receiving tank of about 250 cu. ft. capacity make up a convenient-sized arrangement for weighing feedwater The receiving tank should preferably be at a level corresponding with the usual locomotive tank so that the head of water at the feed pump or injector will be that found in practice. The overflow from the injector should be caught in a small tank (30 to 50 cu. ft.) and returned to the receiving tank so that there will be no need to make correction for loss of feedwater at this point. Platform scales with one tare beam for weighing coal should be of about 2500 lb. capa ity, and the coal can be conveniently handled in wagons holding 1000 lb. each.

Whenever possible, it is best to arrange such gages as are required on supports apart from the locomotive and to use small copper or lead tubing in making connections. The pressure gage belonging to the locomotive usually has a scale of graduation which is too coarse for use in tests and its location in the cab is not satisfactory on account of inaccessibility and vibration. This gage should remain in place and new connection should be made in the pipe leading to it, and a gage having suitable range and graduated to single pounds should be connected and mounted on a firm support near the cab.

The gage glass which is used in determining the height of water in the boiler should be so connected as to give correct indications of water level. This can usually be assured by making the top gage-glass connection through the roof sheet somewhat forward of the back head sheet.

In the locomotive smokebox the draft pipes should extend to the vertical center line, one in front of and one back of the diaphragm. The draft pipes may be $^1/_4$-in. iron pipe and should have a plain open end facing across the flow of gases so as not to become stopped with cinders. The draft connection to the firebox should be about midway of the length of the grates and about 24 in. above them. This draft pipe can usually be inserted through a staybolt. The draft pipe in the ashpan should have its open end at a point near the center of the grates.

Figs. 1 and 2 present diagrams showing the approximate location of a number of the instruments used during locomotive tests. Judgment must always be exercised in the location of instruments in order that data may be secured which are truly representative of the conditions which are to be determined.

The locomotive speed should be measured by a revolution counter applied, preferably, to the main drivers. A speed indicator, as of the electromagnetic type, with the indicating dial in view of the speed-control operator, should also be used.

The indicator driving rig should be rigid and of a form which will not introduce errors in the motion of the indicator drum. Frequent inspection of the parts subject to wear should be made and lost motion should be eliminated.

The steam-sampling apparatus should, ordinarily, be located in the steam dome in such a manner as to obtain as representative a sample as may be possible. A throttling calorimeter is generally the most satisfactory type of instrument to use. In case the amount of moisture in the steam is so great that it cannot be measured with a throttling calorimeter, a separating calorimeter should also be used.

The sample of gases for the flue- or smokebox-gas analysis should be drawn from the region near the center of the main body of escaping gases, using a sampling device designed to collect a representative sample of the gases. Such a sampling device may be made from $^1/_2$-in. iron pipe and may be introduced horizontally through the smokebox front, preferably about the center of the gas passage between the bottom of the smokebox and the table plate. The entrance end of the pipe should be bent to form a part extending across the current of gases and this part should contain perforations opening toward the current of the gases, the collection area of the perforations being less than the area of the pipe.

13f Fuel. The coal used should, in general, be of some kind that is regarded as a standard for locomotives of the same general kind and service as the locomotive undergong test, or standard for the locality where the test is made. The fireman should have sufficient familiarity with the coal used, or be otherwise able to handle it satisfactorily. Where tests are made with a special object in view it may be necessary to select the fuel in accordance with that object.

13g Preparatory Tests and Determinations. Certain preliminary or auxiliary tests are in general necessary or desirable:

I A calibration of the boiler, which in particular will show the

weight of water contained in that part of the boiler corresponding to the gage glass, should be made previous to the test proper.

II The rate of discharge of steam through the safety valves should be determined

III Tests of or determinations concerning auxiliary equipment should be made to determine the conditions under which they are operating and the amount of steam and coal required for their operation.

13h Sampling Coal. Previous to or during the progress of the trial, the coal should be sampled in the manner provided for in Pars. ——— of the code section on Fuels. Too much emphasis can hardly be placed on the importance of proper coal sampling.

13i Chemical Analyses and Calorific Determinations. Chemical analyses and calorific determinations of the coal sample are to be made in accordance with Pars. ——— of the Test Code on Fuels, as are also the chemical analyses of the front-end gases.

13j Ash and Cinders. The ash withdrawn from the ashpan, or elsewhere collected, and the cinders from the front end or cinder collector shall be sampled as nearly in accordance with the directions for sampling coal as circumstances will permit. For the samples of the ash and cinders, calorific determinations shall be made in the same manner as similar determinations for coal. Chemical analyses, at least to the extent of determining the combustible content of the ash and cinders, are to be made in accordance with the methods governing the coal analyses.

Operating Conditions

14 Determine what the operating conditions are to be and note the information and directions given in Par. 10 of the General Instructions. In general, the predetermined operating conditions, the effect or relation of which are to be studied, or such operating conditions as appreciably affect the test, should be maintained as nearly uniform during the test as the limitations of the work will permit. There should be, in general, uniformity in such matters as steam pressure, times of firing, quantity of fuel supplied at each firing, speed, rate of supplying feedwater, cut-off, and in the load applied. It is particularly important that the firing should be in the hands of skilled firemen and that, in so far as may be possible, one fireman be used throughout any one test or series of tests which are to be compared.

15 Unless special conditions require otherwise, the locomotive undergoing test should be practically free from scale, and during a test or series of tests it should also be free from unusual accumulations of sediment. During a long series of tests such boiler washing and other cleaning of the heating surfaces must be arranged for as, in the judgment of the test directors, will give most representative and reliable results. Records should be made concerning such washings or cleaning operations as are carried on. The fire side of the heating surface should in like manner be practically clean before starting a test and should be maintained in uniformly good condition in this respect throughout a series of tests. Whenever there is a liability of even moderate cinder accumulations upon the back tube sheet or in the superheater flues, or the accumulation of loose ash and cinders in the flues and tubes, such parts should be cleaned prior to each test. In general, tubes and flues should be inspected after each one or two tests, or daily, and blown out as may be necessary and as test conditions permit. Where more thoroughgoing cleaning operations may be required, as in a long series of tests, such operations should be conducted at comparatively short intervals of time and record kept thereof.

Starting and Stopping

16 Consult Pars. 16, 17 and 18 of the General Instructions. Preferably, fires should be built up from a clean grate for each test. Where this is impracticable, the fire having been thoroughly cleaned, and banked when necessary, the bank should be broken up and fresh fuel supplied. The locomotive should be started and run, at the speed of the test, a sufficient length of time to build a level fire. All conditions of fire and speed having become uniform, the locomotive should be operated for at least ten minutes under the predetermined operating conditions before the test should begin. On signal observe the fire conditions, steam pressure, water level in boiler, and the time, and record the latter as the starting time of the test. The ashpan should be clean at the starting signal. In closing a test, simultaneous observations should be made upon steam pressure, water level, and fire conditions, and the time recorded as the close of the test. When the test is completed, the ashpan should be cleaned, and the ashes and cinders accumulated during the test should be collected as soon as possible.

17 In general, it is extremely desirable that such firebed conditions may be maintained as will permit substantially the same amount of combustible upon the grate at the start and at the close of the test. It is also, in general, desirable to close a test with the same or practically the same steam pressure and water level as obtained at the start of the test.

Duration

18 The duration of a laboratory test of a locomotive will depend to some extent upon the character of the fuel used, the rate of combustion, and the working limitations of the moving parts. The test should preferably be continued until at least 25 lb. equivalent evaporation of water per square foot of water-heating surface has been obtained. If however, the coal and water consumption are uniform, tests of three hours will be sufficiently long in any case.

Records

19 Consult Pars. 20 to 30 of the General Instructions for directions concerning records. The data should be taken in such manner that the test may be subdivided into a number of comparatively short periods and that the leading data thus obtained for any one or more of such periods may show the degree of uniformity obtained. Coal and water observations in particular should be taken in such manner as to facilitate subdivision of this kind. Observations in general should be taken every ten minutes and when it is essential that a number of observations be taken simultaneously, a sufficient number of observers must be available.

Calculation of Results

20 Pars. 31 to 35 of the General Instructions present information with regard to working up data. The present section, Calculation of Results, gives in detail methods for calculating the results listed in Table 1 excepting those items whose determination is more or less self-evident. For additional directions relative to methods of calculating boiler and engine results, reference may be made to Pars. —— and —— of the Boiler Code and Pars. —— and —— of the Engine Code. For methods of calculating results pertaining to auxiliary apparatus, reference should be made to the individual codes relating to such apparatus.

21 The events of the stroke and the corresponding pressures should be determined for each indicator diagram by inspection and measurement. The values recorded should be averages of the determinations made from individual diagrams. Indicated-horsepower calculations should be made for each indicator diagram. Pars. 13 and 13a of the code for reciprocating steam engines outline the method to be employed.

22 The "heat distribution" or "heat balance," Item 41 of Table 1, should be calculated in accordance with the instructions given in the Boiler Code, Pars. ———, under Computations for Test with Solid Fuels.

Method of Calculating Individual Items

Item 22 Revolutions of Driving Wheels per Minute:

$$\frac{\text{Item } 22(a)}{\text{Item } 18 \times 60}$$

Item 22(*b*) Speed Equivalent of R. P. M., Miles per Hour:

$$\frac{\text{Item } 22 \times \text{Item } 3(c) \times 60}{5280}$$

Item 22(*d*) Piston Speed, Feet per Minute:

$$\frac{[\text{Item } 13(a) + \text{Item } 14(a)] \times \text{Item } 22}{12}$$

Item 23 Temperature of Feedwater:

This is the temperature of the feedwater taken before heat is added to it from the locomotive in any way. In the case of locomotives equipped with feedwater heaters, particularly when exhaust steam or condensate is returned to the feedwater supply, Item 23 must be so determined as to give the locomotive credit for all heat transferred to the feedwater by this exhaust steam or condensate added.

Item 24(*e*) Relative Humidity, Moisture per Pound of Dry Air, Pounds:

The relative humidity should be determined by the use of apparatus as described in Pars. ——— of the code on Instruments and Apparatus. The Locomotive Code assumes that the relative humidity will be calculated from the temperature data taken from wet- and dry-bulb thermometers.

Item 26(c) Barometric Pressure, Pounds per Square Inch:

The barometric pressure should be obtained from a suitable barometer as described in Pars. ——— of the code on Instruments and Apparatus. No correction need ordinarily be made to the observed values.

Item 30 Smoke, Percentage as Observed:

Smoke-density determinations should ordinarily be made through the use of the Ringlemann smoke charts as described in Pars. —— to —— of the code on Instruments and Apparatus.

Item 32(a) Dry Coal Fired, Total, Pounds:

$$\text{Item 32} \times \frac{100 - \text{Item 28}(g)}{100}$$

Item 34 Quality of Steam in Dome, Per Cent:

Quality of steam in the dome when determined by means of a throttling calorimeter should be calculated by the formula:

$$x_0 = \frac{H_c + 0.47 \times (t_r - t_c) - h_0}{L_0}$$

where

x_0 = quality of steam
t_r = observed temperature in calorimeter
t_c = temperature of saturated steam at pressure in calorimeter
h_0 = heat of liquid due to boiler pressure
H_c = total heat of dry steam at calorimeter pressure
L_0 = latent heat of dry steam due to boiler pressure.

Item 34 should be an average of the individual determinations of x_0.

Item 34(a) Superheat in Branch Pipe, Degrees:

Item 24 — t_b

where

t_b = temperature of saturated steam at branch-pipe pressure.

Item 35 Water Evaporated, Total, Pounds:

Item 35(a) + Item 35(c) — Item 35(d)

Item 35(a) Water Delivered to Boiler:

In the case of locomotives not equipped with feedwater heaters or those equipped with heaters which do not return any exhaust steam or condensate to the feedwater supply, the determination of the total water delivered to the boiler is generally readily arranged for. In the case of locomotives equipped with open feedwater heaters or other heaters in the operation of which exhaust steam or condensate is returned to the feedwater supply, special provision must be made to determine the total amount of water delivered to the boiler. This is to be done in such a way that both the total water delivered to the boiler and the amount of the exhaust steam or condensate additions are determined. Furthermore, in the case of locomotives in which exhaust steam or condensate is returned to the feedwater supply, all results involving water or steam supply must be so calculated that, first, items of boiler performance will credit the boiler with all heat transferred to the water and steam; second, items of engine performance will charge the engines with all of the steam (or heat) delivered to them; and third, items of general locomotive performance will show the proper relations between locomotive output and the amounts of coal and water delivered to the locomotive. The type and arrangement of the feedwater heater will, to a large extent, determine the original observations which must be made, the methods which must be employed in making them, and the manner in which subsequent calculations must be modified in order to properly include the performance of the feedwater heater.

In general, in testing locomotives with feedwater heaters, in addition to the determination of the amount and temperature of the inlet water, there should be determined the temperature of the outlet water and, in the case of open heaters, the temperature and pressure of the exhaust steam going to the feedwater heater. Wherever the feedwater supply is heated through the return of exhaust steam or condensate, sufficient observations must be made concerning the amounts and temperatures of the water affected to make possible the calculations of boiler, engine, and overall performance already mentioned.

In case that a more complete test of the feedwater heater is desired than that involved in determining the performance and efficiency of the locomotive as outlined in this code, reference should be made to the Test Code for Feedwater Heaters.

Item 35(b) Weight of Water in Boiler at Start of Test Minus. Weight of Water in Boiler at Close of Test, Pounds:

This item may be obtained from the boiler gage-glass calibration. The total weight of the water in the boiler should be determined from a calibration which may be made by filling the boiler with weighed water or may be made approximately through calculations based upon the boiler dimensions.

Item 35(c) Boiler Corrections for Change of Water Level and Change of Pressure in the Boiler from Start to Close of Test may be calculated by the formula:

$$\frac{w_i\,(h_a + xL - h_i) - w_f\,(h_a + xL - h_f)}{h_a + xL - h}$$

where

w_i = initial weight of water in the boiler, pounds
w_f = final weight of water in the boiler, pounds
h_a = heat of liquid due to average boiler pressure
x = quality of steam, average
L = latent heat of dry steam due to average boiler pressure
h_i = heat content of liquid at start of test
h_f = heat content of liquid at close of test
h = heat content of liquid due to average feedwater temperature.

In case that the test can be closed with approximately the same water level and the same boiler pressure as obtained at the the start of the test, the boiler correction becomes small and may ordinarily be disregarded.

Item 35(d) Water Losses, Pounds:

The hot water, as measured or estimated, which is lost through leaks or otherwise.

In case that this loss is considerable it may seem desirable to substitute, for Item 35(d), as just defined, a corrected value which will take account of the heat transferred to the lost water. This "corrected hot-water losses" may be calculated as follows:

$$\text{Water losses (lb.)} \times \frac{xL}{h_a + xL - h}$$

Ordinarily no attempt need be made to apply this correction.

Item 35(e) Moist Steam Lost or Used Other Than That Going to the Main-Engine Cylinders, and—

Item 35(f) Superheated Steam Lost or Used Other Than That Going to the Main-Engine Cylinders:

Items 35(e) and 35(f) should be measured or estimated as circumstances and available data will permit. Preliminary runs or determinations may be useful in the determination of these items. In the final report Items 35(e) and 35(f) should be shown subdivided into such separate items as may seem desirable and the data taken will permit, in order to show the total and hourly quantities of steam used by the different auxiliaries.

Item 36 Steam to Superheater per Hour, Pounds:

$$\frac{\text{Item 35}(a) + \text{Item 35}(b) - \text{Item 35}(d) - \text{Item 35}(e)}{\text{Item 18}}$$

Item 36(a) Moist Steam per Hour, Pounds:

$$\frac{\text{Item 35}}{\text{Item 18}}$$

Item 36(b) Heat Transfer Across Water-Heating Surface per Hour, Thousands of B.t.u.:

$$\frac{\text{Item 36}(a) \times (h_a + xL - h)}{1000}$$

$h_a + xL - h$ = the heat added to each pound of water evaporated by the boiler exclusive of the superheater.

Item 36(c) Heat Transfer Across Superheating Surface per Hour, Thousands of B.t.u.:

$$\frac{\text{Item 36} \times (H_s - h_a - xL)}{1000}$$

$H_s - h_a - xL$ = the heat added to each pound of steam passing through the superheater.

H_s = total heat of steam at branch pipe pressure.

Item 37 Total Heat Transfer per Hour, Thousands of B.t.u.:

Item 36(b) + Item 36(c)

Item 37(a) Heat Transfer per Hour per Sq. Ft. of Heating Surface, Thousands of B.t.u.:

$$\frac{\text{Item 37}}{\text{Item 11}}$$

Item 39 Superheated Steam per Hour, Pounds:

$$\frac{\text{Item 37} \times 1000}{H_s - h}$$

Item 40(b) Superheated Steam per Hour per Sq. Ft. of Heating Surface:

$$\frac{\text{Item 39}}{\text{Item 11}}$$

Item 41 Efficiency of Boiler, Per Cent:

$$\frac{\text{Item 37} \times 1000}{\text{Item 33} \times \text{Item 28}} \times 100$$

Item 42 Steam Delivered to the Engines per Hour, Pounds:

Item 36 — Item 35(f)

Item 42(a) Coal-as-Fired Equivalent of the Water and Steam Losses, Pounds per Hour:

$$\frac{\text{Item 39} - \text{Item 42}}{\text{Item 40}}$$

Item 42(b) Dry-Coal Equivalent of the Water and Steam Losses, Pounds per Hour:

$$\frac{\text{Item 39} - \text{Item 42}}{\text{Item 40}(a)}$$

Item 45 Coal as Fired per I.Hp. per Hour, Pounds:

$$\frac{\text{Item 33} - \text{Item 42}(a)}{\text{Item 44}}$$

Item 45(a) Dry Coal per I.Hp. per Hour, Pounds:

$$\frac{\text{Item 33}(c) - \text{Item 42}(b)}{\text{Item 44}}$$

Item 46 Steam per I.Hp. per Hour, Pounds:

$$\frac{\text{Item 42}}{\text{Item 44}}$$

Item 46(a) B. T. U. of Coal Consumed per I. Hp. per Hour:

Item 45 × Item 28

Item 47 Drawbar Horsepower:

$$\frac{\text{Item 3}(c) \times \text{Item 22} \times \text{Item 47}(a)}{33{,}000}$$

Item 48 Coal as Fired per Drawbar Horsepower per Hour, Pounds:

$$\frac{\text{Item 33}}{\text{Item 47}}$$

Item 48(a) Dry Coal per Drawbar Horsepower per Hour, Pounds:

$$\frac{\text{Item 33}(c)}{\text{Item 47}}$$

Item 49 Steam per D.Hp. per Hour, Pounds:

$$\frac{\text{Item 36}a}{\text{Item 47}}$$

Item 49(a) B. T. U. of Coal Consumed per D.Hp. per Hour:

Item 48 × Item 28

Item 50 Friction Horsepower:

Item 44 — Item 47

Item 50(a) Locomotive Friction Expressed as Drawbar Pull, Pounds:

$$\frac{\text{Item 50} \times 33000}{\text{Item 3}(c) \times \text{Item 22}}$$

Item 51 Machine Efficiency of the Locomotive, Per Cent:

$$\frac{\text{Item 47}}{\text{Item 44}} \times 100$$

Item 52 Efficiency of the Locomotive, Per Cent:

$$\frac{2545}{\text{Item 49}(a)} \times 100$$

Final Report

23 The data and results should be reported in accordance with the form, Table 1, given herewith. Pars. 36 and 37 of the General Instructions present information regarding the form and substance of a final report. Under Item 10 of Table 1 the various pieces of auxiliary apparatus which are used should, if special, be named and either here or elsewhere in the final report such dimensions and descriptions of the apparatus should be given as will be of assistance in making clear test conditions and test results.

24 It is desirable that the test number and the test designation be so given that each test or run may be readily distinguished from any other test or run. This end would be accomplished for a given laboratory if that laboratory would issue test numbers consecutively. Where a number of runs or trials constitute a series of tests it is also desirable to so select test numbers that different tests series may be somewhat readily distinguished one from the other. The test designation should give in brief form certain important test conditions which will be useful for reference purposes. Uniformity in the form of the test designation as between different series of test and as between different laboratories is desirable. The following is recommended as a suitable form for the test designation: *** — ** — * where the digits *** express speed in revolutions per minute, the digits ** express cut-off in per cent, and the letter F or P, (the final digit, *) indicates a full or a partially opened throttle.

TABLE 1 DATA AND RESULTS OF LABORATORY TEST OF A LOCOMOTIVE

A S.M.E. Code of 19—

(1) Test number:
  (a) Test designation..........
(2) Test of:
  (a) Test made at..........
  (b) To determine..........
  (c) Test conducted by..........
  (d) Locomotive, type and class..........
  (e) Locomotive, number of..........

Dimensions and Proportions

(3) Rated tractive force.......... lb.
  (a) Driving wheels, number of pairs..........
  (b) Driving wheels, nominal diameter.......... in.
  (c) Driving wheels, average circumference, measured.......... ft.
  (d) Driving wheels, average diameter, measured.......... in.
  (e) Engine truck wheels, number of pairs..........
  (f) Engine truck wheels, diameter.......... in.
  (g) Trailing wheels, number of pairs..........
  (h) Trailing wheels, diameter.......... in.
(4) Wheelbase, driving.......... in.
  (a) Wheelbase, total.......... ft.
  (b) Gage of wheels.......... in.
(5) Weight of locomotive, with water at second gage cock and average fire.......... lb.
  (a) Weight on leading truck.......... lb.
  (b) Weight on drivers.......... lb.
  (c) Weight on trailing truck.......... lb.
  (d) Weight of tender, loaded.......... lb.
  (e) Capacity of tender, coal.......... tons
  (f) Capacity of tender, water.......... gal.
(6) Boiler, type..........
  (a) First ring, outside diameter.......... in.
  (b) Tubes, number..........
  (c) Tubes, outside diameter.......... in.
  (d) Tubes, thickness.......... in.
  (e) Superheater flues, number..........
  (f) Superheater flues, outside diameter.......... in.
  (g) Superheater flues, thickness.......... in.
  (h) Length between tube sheets.......... in.
  (i) Fire area of tubes and flues.......... sq. ft.
  (j) Arch tubes, number..........
  (k) Arch tubes, outside diameter.......... in.
  (l) Arch tubes, thickness.......... in.
  (m) Arch tubes, length.......... in.
  (n) Firebox, length.......... in.
  (o) Firebox, width.......... in.
  (p) Firebox, depth.......... in
  (q) Firebox, volume.......... cu. ft.
  (r) Fire doors, number..........
  (s) Fire-door openings, area.......... sq. ft.
  (t) Fire doors, hand or power operated..........
  (u) Water space in boiler below second gage cock.......... cu. ft.
  (v) Steam space in boiler above second gage cock.......... cu. ft.
(7) Grate area.......... sq. ft.
  (a) Grate, width.......... in.
  (b) Grate, length.......... in.
  (c) Grate, style of..........
(8) Air inlets to firebox, total.......... sq. ft.
  (a) Air inlets through grate.......... sq. ft.
  (b) Air inlets above the fuel bed..........
  (c) Ratio of air inlets through grate to grate area.......... per cent
  (d) Ratio of total air inlets to grate area.......... per cent
  (e) Area of air inlets to ashpan.......... sq. ft.
  (f) Ratio of ashpan air inlets to area of tube and flue opening.......... per cent
(9) Superheater, type..........
  (a) Superheater elements, number..........
  (b) Superheater elements, length in flue.......... in.
  (c) Superheater tubes, outside diameter.......... in.
  (d) Superheater tubes, thickness.......... in.
(10) Auxiliary apparatus:
  (a) Brick arch
  (b) Feedwater heater
  (c) Stoker
  (d) Reverse gear
  (e) Air compressor
  (f) Electric generator
  (g) Grate shaker
  (h) Injectors
  (i) Safety valves
  (j) Thermic siphons
  (k) Circulating plates
  (l) Booster engines
(11) Heating surface, total, based on inside of firebox, fire side of tubes, flues, arch tubes and superheater.......... sq. ft.
  (a) Heating surface of the tubes and flues, fire side.......... sq. ft.
  (b) Heating surface of the firebox, fire side.......... sq. ft.
  (c) Heating surface of superheater, fire side.......... sq. ft.
  (d) Heating surface of arch tubes, fire side.......... sq. ft.
(12) Exhaust nozzle, type.......... in.
  (a) Dimensions,.......... in.
  (b) Area, net,.......... sq. in.
(13) Cylinder diameter, right side.......... in
  (a) Piston stroke, right side.......... in.
  (b) Piston-rod diameter, right side.......... in.
  (c) Tail-rod diameter, right side.......... in.
  (d) Clearance, right side, head end.......... per cent
  (e) Clearance, right side, crank end.......... per cent
(14) Cylinder diameter, left side.......... in.
  (a) Piston stroke, left side.......... in.
  (b) Piston-rod diameter, left side.......... in.
  (c) Tail-rod diameter, left side.......... in.
  (d) Clearance, left side, head end.......... per cent
  (e) Clearance, left side, crank end.......... per cent
(15) Valves, type..........
  (a) Steam ports, area.......... sq. in.
  (b) Valve travel, maximum.......... in.

(c) Steam lap ... in.
(d) Exhaust lap ... in.
(e) Valve motion, type ...

(16) Ratio of heating surface to grate area:
(a) Ratio of fire area through tubes and flues to grate area ...
(b) Ratio of firebox heating surface to grate area ...
(c) Ratio of tube and flue surface to firebox heating surface ...
(d) Ratio of firebox volume to grate area ...

Date, Duration, Etc.

(17) Date ...
(18) Duration of test ... hr.
(19) Coal, kind and size:
(a) Method of firing ...
(b) Firebed, approximate thickness ... in.
(20) Reverse lever position ...
(21) Throttle opening ...

Speed

(22) Revolutions of driving wheels per min ...
(a) Revolutions of driving wheels, total ...
(b) Speed equivalent of r.p.m ... miles per hour
(c) Equivalent length of run ... miles
(d) Piston speed ... ft. per min.

Boiler Performance

Average Pressures, Temperatures, Etc.:

(23) Temperature of feedwater ... deg. fahr.
(24) Temperature of steam in branch pipe ... deg. fahr.
(a) Temperature of steam in exhaust passage ... deg. fahr.
(b) Temperature of laboratory, dry-bulb ... deg. fahr.
(c) Temperature of laboratory, wet-bulb ... deg. fahr.
(d) Outdoor temperature ... deg. fahr.
(e) Humidity, moisture per pound of dry air ... lb.
(25) Temperature in smokebox ... deg. fahr.
(a) Temperature in firebox ... deg. fahr
(26) Boiler pressure, gage ... lb. per sq. in.
(a) Branch-pipe pressure ... lb. per sq. in.
(b) Exhaust-passage pressure ... lb. per sq. in.
(c) Barometric pressure ... lb. per sq. in.
(27) Draft in smokebox, front of diaphragm ... in. of water
(a) Draft in smokebox, back of diaphragm, below superheat damper ... in. of water
(b) Draft in firebox ... in. of water
(c) Draft in ashpan ... in. of water

Heating Value and Analysis of Coal, Ash and Cinders:

(28) Heating value per pound of coal as fired ... B.t.u.
(a) Heating value per lb. of dry coal ... B.t.u.
(b) Heating value per lb. of combustible ... B.t.u.
(c) Heating value per lb. of cinders ... B.t.u.
(d) Heating value per lb. of ash ... B.t.u.

Proximate Analysis of Coal as Fired:
(e) Fixed carbon ... per cent
(f) Volatile matter ... per cent
(g) Moisture ... per cent
(h) Ash ... per cent
(i) Sulphur, determined separately ... per cent

Ultimate Analysis of Coal as Fired:
(j) Carbon ... per cent
(k) Hydrogen ... per cent
(l) Nitrogen ... per cent
(m) Oxygen ... per cent

Analysis of Ash:
(n) Carbon ... per cent
(o) Earthy matter ... per cent
(p) Moisture ... per cent

Analysis of Cinders:
(q) Carbon ... per cent
(r) Earthy matter ... per cent
(s) Moisture ... per cent

Analysis of Dry Smokebox Gases, by Volume

(29) Carbon dioxide (CO_2) ... per cent
(a) Oxygen (O_2) ... per cent
(b) Carbon monoxide (CO) ... per cent

Smoke:

(30) Percentage of smoke as observed ... per cent

Cinders and Ash:

(31) Total ash collected from ashpan ... lb.
(a) Ash collected, per cent of total dry coal fired ...
(b) Ash by analysis, total ... lb.
(c) Ash collected, per cent of ash by analysis ...
(d) Cinders collected in smokebox ... lb.
(e) Cinders discharged from stack ... lb.
(f) Cinders, total ... lb.
(g) Ratio of weights, total cinders to total dry coal fired ...

Coal and Rate of Combustion:

(32) Coal fired, total ... lb.
(a) Dry coal fired, total ... lb.
(b) Combustible, by analysis, total ... lb.
(33) Coal as fired per hour ... lb.
(a) Coal as fired per hour per sq. ft. of grate surface ... lb.
(b) Coal as fired per hour per cu. ft. of firebox volume ... lb.
(c) Dry coal fired per hour ... lb.
(d) Dry coal fired per hour per sq. ft. of grate surface ... lb.

Quality of Steam:

(34) Quality of steam in dome ... per cent
(a) Superheat of steam in branch pipe ... deg. fahr.
(b) Superheat in exhaust steam ... deg. fahr.

Water and Steam:

(35) Water evaporated, total ... lb.
(a) Water delivered to boiler ... lb.
(b) Weight of water in boiler at start of test minus weight of water in boiler at close of test (plus or minus) ... lb.
(c) Boiler correction ... lb.
(d) Water losses ... lb.
(e) Moist steam used at auxiliaries, calorimeter, safety valve, steam leaks, etc., total ... lb.
(f) Superheated steam used or lost before reaching the engine cylinders, total ... lb.

Evaporation:

(36) Steam to superheater per hour ... lb.
(a) Moist steam per hour ... lb.
(b) Heat transfer across water heating surface per hour (units of evaporation) ... 1000 B.t.u.
(c) Heat transfer across superheating surface per hour (units of evaporation) ... 1000 B.t.u.
(37) Total heat transfer per hour (units of evaporation) ... 1000 B.t.u.
(a) Heat transfer per hour per sq. ft. of heating surface (units of evaporation) ... 1000 B.t.u.
(38) Units of evaporation per pound of coal as fired ... 1000 B.t.u.
(a) Units of evaporation per pound of dry coal ... 1000 B.t.u.
(39) Superheated steam per hour ... lb.
(40) Superheated steam per lb. of coal as fired ... lb.
(a) Superheated steam per pound of dry coal ... lb.
(b) Superheated steam per hour per sq. ft. of heating surface ... lb.

Efficiency and Heat Distribution (per cent of heat units fired):

(41) Efficiency of boiler and furnace (heat absorbed by boiler) ... per cent
(a) Loss of heat due to moisture in coal ... per cent
(b) Loss of heat due to moisture in air ... per cent
(c) Loss of heat due to hydrogen content of coal ... per cent
(d) Loss of heat due to heat in escaping gases ... per cent
(e) Loss of heat due to escaping combustible gases ... per cent
(f) Loss of heat due to cinders ... per cent
(g) Loss of heat due to ashpan losses ... per cent
(h) Loss of heat due to radiation and unaccounted for ... per cent

Engine Performance

Steam to Engines:

(42) Steam delivered to the engines per hour ... lb.
(a) Coal-as-fired equivalent of the water and steam losses per hour ... lb.
(b) Dry-coal equivalent of the water and steam losses per hour ... lb.

Events and Pressures from Indicator Diagrams, Averages:

(43) Mean effective pressure ... lb. per sq. in.
(a) Cut-off ... per cent of stroke
(b) Steam-chest pressure ... lb. per sq. in.
(c) Initial pressure ... lb. per sq. in.
(d) Pressure at cut-off ... lb. per sq. in.
(e) Least back pressure ... lb. per sq. in.

Indicated Horsepower:

(44) Indicated horsepower ... i.hp.
(a) Right side, head end ... i.hp.
(b) Right side, crank end ... i.hp.
(c) Left side, head end ... i.hp.
(d) Left side, crank end ... i.hp.
(45) Coal as fired per i.hp. per hour ... lb.
(a) Dry coal per i.hp. per hour ... lb.
(46) Steam per i.hp. per hour ... lb.
(a) B.t.u. of coal consumed per d.hp. per hour ...

General Locomotive Performance

Drawbar Horsepower:

(47) Drawbar horsepower ... d.hp.
(a) Average drawbar pull ... lb.
(48) Coal as fired per d.hp. per hour ... lb.
(a) Dry coal per d.hp. per hour ... lb.
(49) Steam per d.hp. per hour ... lb.
(a) B.t.u. of coal consumed per hour ...

Locomotive Friction:

(50) Friction horsepower . . . .

(a) Locomotive friction expressed as pull at drawbar . . . . . . lb.

Efficiency:

(51) Machine efficiency of the locomotive . . . . per cent

(52) Efficiency of the locomotive . . . . per cent

Test Code for Road Test

Object of Test

25 The object of a road test, as covered by this code, is the determination of the coal and steam consumption of a locomotive per unit of power under the conditions of road service.

26 If the object of the test differs from that for which the code is specifically prepared, the particular object should be determined and recorded in accordance with the suggestions of Pars. 1, 2 and 3 of the General Instructions and the entire conduct of the test should be in accord with the object in view.

27 Locomotive road tests are inherently less accurate than laboratory tests. The precise measurement of coal and water is much more difficult on the road, as well as the determination of some of the other data. Under the usual conditions of road service there are bound to be wide fluctuations in speed, drawbar pull, and rate of firing, all fundamental factors in performance; and even under the most rigid control much of this variation will inevitably remain and exercise an important influence on the results. In a locomotive, cut-off and speed, for example, vitally affect the steam consumption, which varies widely with both; and boiler performance likewise varies greatly with the rate at which the boiler is driven. In short, in a road test we are dealing with a power plant operating under speeds and loads which frequently vary from zero to more than 100 per cent above the average.

28 If the purpose of the test, therefore, is such as to make necessary an accurate determination of the water rate or rate of evaporation, road tests will not give reliable results and the locomotive must be tested in a laboratory. There are other purposes for which road tests are inherently unsuited. Whatever their purpose, road tests are difficult to make, and unless they are thoroughly prepared for and conducted with great skill and care their results are likely to be misleading and frequently worse than useless.

Measurements

29 The principal determinations which must be made in a road test of a locomotive are:

(a) The engine and driving-wheel dimensions for horsepower calculations
(b) The leading boiler dimensions such as grate surface, heating surface, and boiler volume, which enter into calculations involving coal and water consumption
(c) The operating conditions such as throttle and reverse-lever positions, which define test conditions
(d) The speed
(e) The indicator diagrams for the determination of horsepower and engine conditions
(f) The temperature of the outside air, the feedwater, the superheated steam, and the front-end gases
(g) The boiler pressure
(h) The draft in the front end
(i) The quality of steam in the dome
(j) The weight of the feedwater and the weight of water and steam lost or used, through leaks, auxiliary apparatus, etc.
(k) The weight of coal fired
(l) The weight of the ash
(m) The chemical analysis and calorific determination of the coal
(n) The composition of the front-end gases
(o) The blackness of the smoke
(p) The drawbar pull
(q) The dimensions and determinations which may be required in connection with such auxiliary apparatus as may constitute a part of the locomotive undergoing test
(r) The length and weight of train, number and kind of cars, distribution of loaded and empty cars in train, and pertinent or unusual conditions regarding lubrication, braking equipment, etc.
(s) Wind, weather, and rail conditions.

Owing to the difficulties ordinarily encountered in locomotive road testing it will in general be found inadvisable to make observations concerning certain of the items mentioned unless conditions therefor are especially favorable and extreme care in connection with such observations can be exercised. The advisability of making observations concerning the following items should be considered:

Quality of the steam
Weight of the ash
Composition of the front-end gases
Blackness of the smoke.

Instruments and Apparatus

30 For road tests it is assumed that a dynamometer is available for registering the amount of the force applied to the train by the locomotive. The use of a dynamometer practically assumes the use of a dynamometer car. A dynamometer car, aside from housing the dynamometer, provides a convenient place for the installation of other measuring, indicating, and recording devices. The code as written provides that in general the testing apparatus will be carried on the locomotive itself. Where a dynamometer car is available a considerable portion of the testing equipment may be advantageously mounted within that car. Certain institutions have dynamometer cars which are available for test purposes and a considerable number of railroad companies own and operate dynamometer cars.

31 The apparatus and instruments required for a road test of a locomotive are:

(a) Dynamometer for determining the pull on the drawbar
(b) Weighing apparatus for fuel and ash
(c) Weighing apparatus for water in order to establish a calibration of the tender water tank
(d) A suitable arrangement of graduated gage glasses or floats on the tender tank for measuring the feedwater
(e) Water meters for measuring the feedwater
(f) Graduated scale attached to the water glass of the boiler
(g) Suitable levels or plumb lines to show the inclination of the boiler
(h) Pressure gages, draft gages, thermometers and pyrometers
(i) Speed-measuring apparatus
(j) Steam-engine indicators with indicator rigging or reducing motion
(k) Steam-sampling apparatus and steam calorimeter
(l) Coal-sampling apparatus
(m) Fuel calorimeter
(n) Air-pump stroke counters
(o) Some portable weighing or measuring apparatus for the determination of water losses or leaks such as injector overflow.

32 Additional directions regarding the use, the calibration, and the accuracy of the instruments mentioned are given in Pars. —— and —— of the code section on Instruments and Apparatus.

Preparation

33 In general, the preparations as given for the laboratory tests should be carried out preparatory to placing the locomotive in service with the understanding that some special directions regarding the installation of the testing appliances which refer to road tests should be followed. Par. 13 and sub-paragraphs 13*a* to 13*j* which relate to preparation for laboratory tests, should be studied.

34 The following directions relate to location of apparatus and special requirements for road tests:

(a) The water meter should be attached to the suction pipe of the injector at a point where it can be conveniently read when the train is in motion. A check valve should be provided to prevent hot water backing through it when starting and stopping the injector. A strainer should also be provided.

(b) The indicator rigging should be particularly rigid and suited to severe service under road conditions without liability to disarrangement during a test. Light tubing should be used to transmit the reduced motion to a point near the indicator. Lack of room and facility of operation make it desirable to use a single indicator for each cylinder, connected to the two ends by three-way cock. The piping to the indicators should be not less than $^3/_4$ in. inside diameter. It is best to carry the pipes to the side of the cylinder opposite the clearance spaces rather than to the cylinder heads or to the steam ports. A branch leading to the steam chest should be provided. Sharp pipe bends should be avoided, and the outside piping should be protected to avoid radiation. Rigidity of the indicator cock is essential and it should be obtained by clamping it securely to the cylinder.

(c) Unless suitable coal-weighing apparatus can be installed upon or near the tender, the coal must be weighed previous to the test and be so arranged upon the tender, by sacking or otherwise, that an accurate record of the coal used may be obtained. Coal taken en route should be delivered to the locomotive with such care that serious error concerning its weight may not occur.

Extreme care and watchfulness are necessary at all times in order to obtain reasonably accurate coal determinations. The method of sacking a part of the coal is one of the most convenient methods for determining the amount of coal used. Under this method all coal to be used should be weighed previous to the test upon scales known to be accurate. The greater

part of the coal, including that taken en route, may be placed in bulk upon the tender in the usual way. The remainder, say, 15 to 20 per cent, is to be placed in sacks containing 100 lb. each. The sacked coal should be used previous to the start of the test, after the close of the test, and preferably during the latter part of the test. It is desirable that all of the bulk coal be consumed during the test; if this is not done the remaining bulk coal must be carefully weighed back.

35 To facilitate the work of the men who operate the indicators and read the instruments at the front end of the locomotive, and to protect them from wind and rain and the jolting of the locomotive, a suitable housing or pilot box should be provided which should extend back to the cylinders and should be securely fastened to the bumper beam. The floor of the pilot box must be above the level of the pistons in order to minimize the danger to the operators in case of such accidents as broken piston rods or broken cylinder heads.

36 Steam used for auxiliary purposes other than in the cylinders such as air pumps, blower, calorimeter, injector overflow, train lighting and heating, and what escapes from the safety valves may be estimated from data obtained by testing such items of apparatus either before or after the trial and from records of the time of their operation or other pertinent data taken during the test. Test data regarding the use of steam for auxiliary purposes should always be taken with sufficient detail and completeness that errors arising from estimates of this kind will be small. If important auxiliary apparatus directly connected with the economical performance of the locomotive, such as the feedwater heater, is part of the locomotive equipment, such auxiliary apparatus should be tested during the trial in accordance with the A.S.M.E. codes applicable to the particular auxiliary apparatus.

37 The coal should be sampled at the time that it is weighed, in the manner provided for in Pars —— to —— of the code section on Fuels. Too much emphasis can hardly be placed upon the importance of proper fuel sampling. In case water is added to the coal after it has been weighed and sampled, a record of the approximate amount of water added should be made. Chemical analyses and calorific determinations of the coal sample are to be made in accordance with Pars. —— to —— of the code section on Fuels. The code for road tests does not provide for the collection of stack cinders, nor for sampling and analyzing ash or cinders. It is only under favorable circumstances that the ash can be collected with sufficient accuracy to warrant so doing. In case that provision is made for collecting ash and cinders and subsequent determinations are desired, the material collected should be sampled, analyzed, and have calorific determinations made in accordance with the instructions for similar determinations as presented in the code for laboratory tests.

Operating Conditions

38 Determine what the main operating conditions are to be and note the information and directions given in Par. 19 of the General Instructions. In a road test the operating conditions are in general those pertaining to the regular service on the railroad. The same general considerations concerning uniformity of conditions will govern during road tests as for laboratory tests in so far as may be possible. The nature of the service performed will, however, preclude the possibility of uniformity in a number of conditions in respect to which practical uniformity can be maintained in laboratory tests. Particular skill or other qualifications of the engineer and fireman may have an important bearing upon test performance, and conditions of this kind should be noted and in general made matters of record. The sanding appliances of the locomotive should be in good condition and slipping of the engines should be avoided where possible.

39 It is often desirable to take special readings of water levels and total weight of coal fired at specified stopping and passing points. Observations should be made throughout the trial of the time of passing mile posts or other designated points; the time the throttle valve is open or closed; the time of arriving at and leaving each station; also the length of time the stoker, safety valve, blower, train-heating system, lighting system and other steam-using apparatus are in operation. A record should be made of the number of injector applications and the overflow water should be measured or estimated and allowed for.

40 If during a run a stop of more than 5 minutes is made a deduction from the total amount of coal fired shall be made in determining the amount of coal used on the test. The amount of coal fired during such a stop should be determined as accurately as possible by firing the coal from a special supply such as sacked coal or by computing the number of scoopfuls of coal fired during the stop. In case the amount is determined by the number of scoopfuls, an average weight of one scoopful of coal should be determined previous to the test for the fireman and for the particular scoop which is to be used. During stops the fire should be maintained in proper condition according to the requirements of the service and as far as possible so that there may be the same amount of unconsumed coal upon the grate at the end of the stop as there was at the beginning of the stop. There should, preferably, be no water supplied to the boiler during stops, and a marked variation in boiler pressure should be avoided. If leakage or other conditions consume appreciable or readily measurable amounts of water during stops, allowance should be made therefor. For stops of less than 5 minutes' duration no allowance will be made for the coal consumed during such stops, and in general no allowance need be made for steam used or lost unless such uses or losses are of considerable magnitude.

Starting and Stopping

41 Consult Pars. 16, 17, and 18 of the General Instructions. The fire having been thoroughly cleaned, built up from a clean grate, or from a properly banked fire, it should be brought to about the thickness that will be required for the run. When the locomotive first starts with its train, observe the fire conditions, steam pressure, water levels, location, and time, and record the latter as the start of the test.

42 During the run the fire should be maintained as level and as uniform as practicable, and when the end of the run is reached the fire should have approximately the same quantity of unconsumed combustible upon the grate as at the start of the test. When the locomotive makes the final stop of the test with its train, the fire, if not already in the desired condition, should be quickly brought to approximately that condition in order to facilitate the determination of the amount of coal burned.

43 When the locomotive makes the final stop of the test with its train, simultaneous observations should be made upon steam pressure, water levels, location, and fire conditions, and the time recorded as the close of the test.

44 In general, it is extremely desirable that the fire conditions be so maintained as to permit substantially the same amount of combustible upon the grate at the start and at the close of the test. Except where fire conditions at start and close of test are known to vary greatly, no correction on this account should be applied in determining the amount of coal burned. The effort should be made to make the difference in unconsumed combustible on the grate, as between the start and close of the test, comparatively small, and to record fire conditions at these times with as great exactness as possible. Where a correction is applied on account of an important variation in fire conditions the final report should show the amount of such correction and the method by which it was determined. It is also, in general, desirable to close a test with the same or practically the same steam pressure and height of water in the boiler as obtained at the start of the test.

45 If the test is to include the complete run of the locomotive, including terminal operations, modifications concerning the handling of the fire, keeping the records, etc. will be required in order to provide for such extension of the test period.

Duration

46 The duration of a road test depends largely upon the length of the run and the service conditions. In general, for freight locomotives a test should not be materially less with regard to time and service than is required in operating over an average freight division. Every effort should be made that errors arising from inability to accurately measure coal and water may not constitute an unduly large percentage of the total coal and water determined. The duration of the test or running time is the elapsed time after the locomotive first starts with the train until the train comes to rest at the designated stopping place, minus the time consumed in

stops. In fast passenger service the runs should be, if practicable, at least 100 miles long.

Records

47 The data should be recorded in the general manner pointed out in Pars. 20 to 30 of the General Instructions, bearing in mind the fluctuating character of the load which often obtains, and that unusual precautions must often be taken to secure accurate information. Through suitable signaling or recording devices the taking of indicator diagrams or other observations such as steam pressure, lever positions, etc., made upon the locomotive may be recorded upon the dynamometer-car chart and coördinated with the time, location, and drawbar-pull records. If the conditions of the proposed test give promise of substantial uniformity and the test is to be of many hours' duration, observations should be made at 10-minute intervals, the drawbar-pull diagram marked at these times, and indicator diagrams taken. If the test is to be of short duration or the fluctuations of power or speed are extreme, shorter intervals should be used; or irregular intervals may be chosen such as will give data most representative of test conditions.

48 Special attention must often be given to matters which will make accurate tonnage records possible, and provision must be made that special conditions concerning wind, weather, track and equipment conditions are adequately recorded.

Calculation of Results

49 The results should in general be calculated in accordance with the methods given in Pars. 19, 20 and 21 of the code for laboratory tests. The code for road tests does not call for all of the data called for by the code for laboratory tests and the same refinement with regard to corrections is not always possible in connection with road-test data that may be desirable in connection with laboratory-test data.

50 Item 17(*a*), Length of Run, equals the total distance over which the locomotive moved the train. This distance is preferably determined from an autographic record showing the distance traveled by the train. Such a record is ordinarily made in connection with the record of drawbar pull. If such a distance record is not obtained Item 17(*a*) should be identical with or determined from Item 22(*c*), Equivalent Length of Run. Item 17(*a*) is to be used in calculating Item (20*i*), Number of Car-Miles, and Item 20(*j*), Number of Ton-Miles. For definition of the terms "ton-miles" and "car-miles" see Par. — of the code section on Definitions and Values.

51 Item 18, Duration of Test or Running Time, is the actual time between the start and stop of the test minus the time consumed in stops. Item 18 is to be used in all calculations leading to the expression of results of coal and steam consumption per hour, and individual determinations of i.hp. or d.hp. leading to average values for i.hp. and d.hp. are to be so selected that the average values will correspond to the time defined by Item 18.

52 The average drawbar pull should be determined preferably from a continuous record of the drawbar pull. If an integrating device is not a part of the recording apparatus, the area of the dynamometer record should be measured by means of a planimeter and this area divided by the length of the record; or the height of the record should be measured directly at a sufficient number of points to give a fair average result. The code provides that the drawbar horsepower is to be calculated from the average drawbar pull. Where it is found desirable to calculate drawbar horsepower for certain instants as at the time certain indicator diagrams are taken, the corresponding drawbar pull should be determined by direct measurement of the dynamometer record for the instant under consideration. The maximum drawbar pull should be measured as an average over a portion of the record which includes at least one revolution of the driving wheels. Items 50 and 51 of the Road Test Code should be calculated in the same way as Items 50 and 51 of the Laboratory Test Code. These items so obtained, however, have a somewhat different significance from those obtained in laboratory tests.

Final Report

53 The data and results should be reported in accordance with the form (Table 2) given herewith. A profile of the route over which the test has been made, showing the principal grades, curves, water stations, etc., should accompany the records of the test. Dynamometer records or selected portions thereof may also become a part of the final report. If records of the throttle and reverse-lever positions are not automatically obtained, it is usually desirable to obtain records showing the position of these levers at certain times during the test, and a report concerning such observations may become a part of the final report. Pars. 36 and 37 of the General Instructions present information regarding the form and substance of a final report.

TABLE 2 DATA AND RESULTS OF ROAD TEST OF LOCOMOTIVE

A.S.M.E. Code of 19—

Note: The first 16 items of this table are identical with the first 16 items in Table 1. When complete this table contains these 16 items.

Date, Duration, Etc.

(17) Date	
(*a*) Length of run	miles
(18) Duration of test (running time)	hr.
(*a*) Actual time between start and stop	hr.
(*b*) Number of stops	
(*c*) Time consumed in stops	hr.
(19) Coal, kind and size	
(*a*) Method of firing	
(*b*) Firebed, approximate thickness	in.
(20) Gross weight of train, excluding the locomotive	tons
(*a*) Number of cars	
(*b*) Number of axles in train behind tender	
(*c*) Open-top cars	
(*d*) Closed cars	
(*e*) Kind of cars (give in such detail as may be desirable)	
(*f*) Loads	
(*g*) Empties	
(*h*) Average weight per car	tons
(*i*) Number of car-miles	
(*j*) Number of 100 ton-miles	
(21) Kind of service	
(*a*) Weather conditions	
(*b*) Wind conditions	
(*c*) Rail conditions	

Speed

(22) Revolutions of driving wheels per minute	
(*a*) Revolutions of driving wheels, total for running time	
(*b*) Speed equivalent of r.p.m.	miles per hour
(*c*) Equivalent length of run	miles
(*d*) Piston speed	ft. per min.
(*e*) Maximum train speed	miles per hour

Boiler Performance

Average Pressures, Temperatures, Etc.:

(23) Temperature of feedwater	deg. fahr.
(24) Temperature of steam in branch pipe	deg. fahr.
(*a*) Outdoor temperature	deg. fahr.
(25) Temperature in smokebox	deg. fahr.
(26) Boiler pressure, gage	lb. per sq. in
(*a*) Branch-pipe pressure	lb. per sq. in.
(27) Draft in smokebox, front of diaphragm	in. of water
(*a*) Draft in smokebox, back of diaphragm, below superheat damper	in. of water

Heating Value and Analysis of Coal:

((28) Heating value per pound of coal as fired	B.t.u.
(*a*) Heating value per pound of dry coal	B.t.u.
(*b*) Heating value per pound of combustible	B.t.u.
Proximate Analysis of Coal as Fired:	
(*c*) Fixed carbon	per cent
(*d*) Volatile matter	per cent
(*e*) Moisture	per cent
(*f*) Ash	per cent
(*g*) Sulphur, determined separately	per cent

Analysis of Dry Smokebox Gases by Volume:

(29) Carbon dioxide (CO_2)	per cent

Smoke:

(30) Percentage of smoke as observed	per cent

Ash:

(31) Total ash collected from ashpan	lb.
(*a*) Ash collected, per cent of total dry coal fired	
(*b*) Ash by analysis, total	lb.
(*c*) Ash collected, per cent of ash by analysis	

Continued on page 625)

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Department of MECHANICAL ENGINEERING are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

The Design of Segmental and Sector Counterbalance Weights

TO THE EDITOR:

The following very convenient formulas for the design of locomotive counterbalance weights of both the segmental and sector forms were devised by H. A. F. Campbell and Emery Walker, of the Baldwin Locomotive Works, and are here presented, together with their derivations, by Mr. Campbell's kind permission.

In Figs. 1 and 2 let

- r = crank radius in inches
- R = outer radius of counterbalance in inches
- R_1 = inner radius of sector counterbalance in inches
- t = thickness of counterbalance in inches
- w = weight of a cubic inch of metal in counterbalance, in pounds
- W = weight at crank pin to be balanced, in pounds
- n number of spaces between spokes to be filled by sector counterbalance
- N = number of spokes in wheel.

Referring to Fig. 1, let l = length of arc ACB subtending the angle $AOB = 2\theta$ radians. Then since

$$\text{area of sector } OACB : \frac{\pi}{4}(2R)^2 : : l : 2\pi R$$

$$\text{area of sector } OACB = \frac{\pi R^2 l}{2\pi R} = \frac{Rl}{2} = \frac{R \times 2R\theta}{2} = R^2\theta$$

The distance of the centroid of the sector $OACB$ from O is

$$\frac{2}{3} R \frac{\sin\theta}{\theta}$$

hence the moment of its area about O is

$$R^2\theta \times \frac{2}{3} R \frac{\sin\theta}{\theta} = \frac{2}{3} R^3 \sin\theta$$

The area of the triangle OAB is

$$\frac{2R\sin\theta \times R\cos\theta}{2} = R^2 \sin\theta\cos\theta$$

and the distance of its centroid from O is

$$\frac{2}{3} R\cos\theta$$

hence the moment of its area about O is

$$R^2 \sin\theta\cos\theta \times \frac{2}{3} R\cos\theta = \frac{2}{3} R^3 \sin\theta\cos^2\theta$$

The difference of these moments is the moment of the area of the segment ABC about O, or

$$\frac{2}{3} R^3 \sin\theta - \frac{2}{3} R^3 \sin\theta\cos^2\theta = \frac{2}{3} R^3 \sin\theta\,(1 - \cos^2\theta) =$$

$$\frac{2}{3} R^3 \sin^3\theta = \frac{2}{3}\left(\frac{AB}{2}\right)^3 = \frac{2}{3}\,\frac{AB^3}{8} = \frac{1}{12} AB$$

hence the moment of the weight of the segment about O is

$$\frac{1}{12} AB^3 tw = Wr$$

and

$$AB = \sqrt[3]{\frac{12\,Wr}{tw}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

Similarly in Fig. 2, the difference of the moments of the areas of the sectors OAB and $OA'B'$ about O is the moment of the area $A'ABB'$ about O, or

$$\frac{2}{3} R^3 \sin\theta - \frac{2}{3} R_1^3 \sin\theta = \frac{2}{3}\sin\theta\,(R^3 - R_1^3)$$

hence the moment of the weight of $A'ABB'$ about O is

$$\frac{2}{3}\sin\theta\,(R^3 - R_1^3)tw = Wr$$

and

$$R_1 = \sqrt[3]{R^3 - \frac{3Wr}{2\sin\theta\, tw}}$$

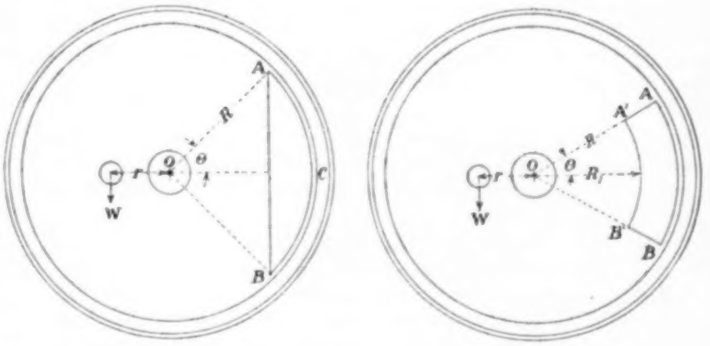

Fig. 1 Fig. 2

FIG. 1 SEGMENTAL-TYPE COUNTERBALANCE WEIGHT

FIG. 2 SECTOR-TYPE COUNTERBALANCE WEIGHT

Substituting for θ radians its sexagesimal equivalent of $\theta°$, then since

$$2\theta° : 360° : : n : N$$

$$2\theta° = 360\frac{n}{N} \text{ or } \theta° = 180\frac{n}{N}$$

and

$$R_1 = \sqrt[3]{R^3 - \frac{3Wr}{2tw\sin\dfrac{180\,n}{N}}} \quad \ldots\ldots\ldots\ldots [2]$$

In applying these formulas t should be assumed.

The writer disclaims all credit for the foregoing beyond that of arranging the expressions and making the drawings.

Formula [1] can be applied to the design of the crescent type of counterbalance weight by determining the length of the chord AB of a segmental counterbalance for the given values of W, r, t and w, and after selecting the radius of the inner arc of the crescent counterbalance, by trial locating the center of this arc so that it will intersect the chord AB at such points that the area cut by the arc from the segment at the central part of the chord will be approximately equal to the sum of the areas added by the arc to the segment at the extremities of the chord, thus maintaining the volume and weight of the counterbalance approximately constant.

While this procedure is of course not accurate, since it ignores the alteration in position of the center of gravity of the counterbalance due to the change of its inner contour, it is thought that it will be found useful for purposes of preliminary design.

New York, N. Y. EDWARD L. COSTER.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING.

Below are given the interpretations of the Committee in Cases Nos. 391, 399 (reopened), 416, 419, 421 and 422, as formulated at the meeting of June 26, 1923, and approved by the Council.

In accordance with the Committee's practice, the names of inquirers have been omitted.

CASE No. 391

Inquiry: Permission is requested, under Par. 245, to operate water-tube boilers with the tubes secured to malleable iron headers at pressures greater than 200 lb. per sq. in. Also, attention is called to the fact that Par. 246*b* requires that the hydrostatic test be applied to all headers with tubes attached, whereas in certain cases it is not customary to attach the tubes until the boilers are erected in the field.

Reply: It has been proposed to revise the requirements of the Boiler Code in regard to the pressure allowance on water-tube boilers when the tubes are secured in malleable iron headers, as follows

"Par. 245—Change '200 lb.' in the third line to '350 lb.'

Par. 246*a*—Add the following to this section:

The malleable iron used for headers of water-tube boilers shall conform to the Specifications for Malleable Castings given in Pars. 111–120 (the paragraphs to be changed to conform with latest A.S.T.M. Specification).

Par. 246*b*—Change '1500 lb.' in the third line to '2250 lb.' Change the last sentence to read:

A hydrostatic test applied to all new headers or elements with tubes attached shall be 500 lb. per sq. in. when cast iron headers or elements are used, and two and one-half times the working pressure when malleable iron is used, although the minimum test pressure with malleable iron headers or elements shall be 500 lb. per sq. in."

CASE No. 399 (Reopened)

Inquiry: (*a*) Is any allowance permissible in the value of T in the formula in Par. 199 of the Code, for the combined thickness of the head and washer applied on the outside thereof under the nut of the through stay, when the washer is of large size and riveted to the head?

(*b*) Is the same increase in the value of T in the formula in Par. 199 applicable when a doubling plate is riveted on the inside of the segment of a head as if it were riveted on the outside of the segment?

Reply: It is the opinion of the Committee:

That the Code does not stipulate whether the doubling plate shall be placed on the inside or outside; it is optional, but the inside plate of your design is preferable;

That the doubling plate must cover the entire segment and be riveted to the head in accordance with the requirements of the Code;

That 75 per cent of the combined thickness of head and doubling plate shall be used in determining T;

That the value of $C = 175$ may be used for washers without doubling plate when stays are fitted with inside and outside nuts and outside washers, where the diameter of the washers is not less than $0.4p$ and the thickness not less than T;

That $C = 175$ may be increased by 15 per cent when both washers and doubling plates are used, designed in accordance with the Code;

That the Code does not provide any additional value for C on account of the washers being riveted to the plate.

CASE No. 416

Inquiry: Information is requested as to the method of calculating, under the Rules in the Boiler Code, the required thickness of the bottom plate of the combustion chamber of a wet-back Scotch marine type of boiler when this bottom plate is curved upward or inward to the form of an arched surface between the points of attachment of the different furnaces and thus requires no staying.

Reply: It is the opinion of the Committee:

That there is no rule in the Code exactly covering the construction submitted;

That the rule which has been followed from the General Rules and Regulations provided by the Board of Supervising Inspectors Steamboat-Inspection Service, Department of Commerce, is not applicable to the design submitted;

That the application of this rule to the case in hand does, however, provide a safe construction. Par. 239*a* of the A.S.M.E. Boiler Code may be used, which is equivalent to the Board of Supervising Inspectors' rule above quoted;

That a safer construction would be obtained if the arch curved plate were either stayed to the outer shell or reinforced;

That it would be better construction to build boilers with separate combustion chambers, with the bottoms so designed that they need not be stayed.

CASE No. 419 (In the hands of the Committee)

CASE No. 421

Inquiry: Is it permissible to electrically weld a boiler shell, particularly the longitudinal joint, if sufficiently reinforced with bands as shown in the blue print, so that no stress is carried by the welded joint?

Reply: It is the opinion of the Committee that a boiler so constructed would not meet the Rules in the Code unless the bands are made strong enough to withstand the full boiler pressure without giving any credit to the holding power of the welded shell, and unless some other method than the autogenous welding shown in the blue print is used for attaching the heads to the shell (see Par. 186 of the Code).

CASE No. 422

Inquiry: Will it be acceptable, under the Rules of the A.S.M.E. Boiler Code, to use angle-iron attachments for the heads to the shell of cylindrical boilers, instead of the American practice of flanging the heads, and also to bolt the furnace front sheet and the rear tube plate to the boiler heads instead of riveting?

Reply: It is the opinion of the Committee that provided the design is in accordance with the requirements of the Code as to material, stresses, construction, workmanship, inspection, and stamping, the boiler so constructed would meet the requirements of the Code.

Bending Stresses in Curved Tubes

(*Continued from page 582*)

As a second example consider the cross-section[1] represented in Fig. 2. In this case

$$h_1/h_2 = 1;\ b/a = 0.785;\ \Lambda = 2640$$

The connecting angles and the external parts of the horizontal plates have no appreciable influence on the distortion of the cross-section, therefore the moment of inertia of their cross-section is included in the moment of inertia i_2. In this way

$$i_1 = 319 \times 10^3\text{cm.}^4;\ i_2 = 307 \times 10^3\text{cm.}^4;\ i_2/i_1 = 0.96$$

Substituting this in [5] gives $\beta = 0.60$. It is seen that in this case the maximum stresses and the flexibility of the tube are $1 : 0.60 = 1.67$ times those given by Formulas [1] and [2].

[1] **Fairbairn crane described in Ernst's Die Hebezeuge, vol. iv, p. 540.**

The Control of Civil Aviation

(Continued from page 576)

Some very interesting proposals for the carriage of mail to remote points, now served with difficulty, have been considered and within a few years air mails will undoubtedly be started. There is at present a United States Post Office contract for the conveyance of mails to a Canadian port to catch outgoing steamers bound for the Orient. This has worked out regularly and smoothly for two years now and is evidently giving satisfaction. It is operated by an American firm on the Pacific Coast. Their machines have been approved for the purpose of entering this country by the Controller of Civil Aviation.

In the event of any accident occurring the Department must be notified and an inquiry is held if considered necessary. Certificates of any class may be suspended at any time for cause by the Department, and this action is taken when the evidence before a court of inquiry points to negligence on the part of the holder. A return must be made to the Department annually, giving any particulars in regard to their operations which the Department may require. This enables reliable statistics as to passengers and freight carried, hours flown, etc., to be compiled.

It will be seen from the foregoing that a system has been instituted giving adequate control of the new form of transportation without undue interference by the state. A word is necessary as to the enforcement of the regulations, the examination of machines and personnel, etc. The inspectors should in all cases be practical flying men with the requisite experience and qualifications to undertake this class of work. If others not so qualified are employed, confidence cannot be maintained in the administration. If, on the other hand, the commercial firms feel that practical men, whose flying experience is beyond question, who understand their difficulties and problems, and who are personally interested in the development of flying, are charged with the administration of the regulations, confidence in the administration is easily gained and maintained. Too great emphasis cannot be laid on the necessity of employing the proper type of inspector.

Conclusion

Similar regulations have been passed by many countries and the experience of the past three years proves that the basis laid down in the International Convention for the control of aviation is sound. There are, and will be, many points on which differences arise owing to the widely varying conditions found in different parts of the world. The International Commission has been instituted for the very purpose of their discussion and settlement, and provides a medium for the mutual exchange of opinions and the settlement of divergent views. The success, under practical working conditions, of the code adopted under the Convention is testimony to the foresight and practical imagination of its framers.

A word may be permitted in conclusion regarding the situation in the United States. Canada and the United States are so closely allied, our interests hold so much in common, and our intercourse is so intimate, that an agreement on international flying between the two countries is essential. As no legislation has been passed so far in the United States providing for the control of aviation, it has not been possible to draw up a convention. The Canadian Government has, however, taken the necessary action in regard to the International Convention to permit such a convention being arranged, in that a derogation has been obtained in favor of the United States from Article 5 of the Convention, which limited our freedom of action in respect of non-contracting states. The government is also supporting an amendment to the same article to permit separate conventions with non-contracting states to be entered into. Canada admits all American machines on the same terms as if the United States had ratified the Convention. That is, we only insist that American machines entering and flying in Canada shall comply with the same regulations as our own. They are not, however, permitted to engage in the carriage of goods or passengers between two Canadian points or other commercial work. Aeronautical opinion in the states has expressed itself with the greatest emphasis on the desirability of passing legislation for the Federal control of aviation. This will be enacted without doubt in the near future. Its necessity must be evident to all. The bills now before Congress show no divergence in essentials from the terms of the International Convention. Some international agreement is essential and whether or not the United States eventually become a party to the present Convention, it is earnestly hoped that the authorities charged with the control of aviation will take no step which will tend to create different standards of control throughout the world from those adopted in Canada and elsewhere. Absolute uniformity is neither necessary nor desirable, but all will agree that a common basis for control and a common set of standards will be of inestimable benefit and will greatly facilitate the growth and progress of commercial aviation.

Preferred-Number Series

(Continued from page 588)

4 *Series for General Machine Construction.* The numbers in these series may be used whenever possible in general machine construction and especially for details not yet standardized, with the purpose of bringing about an automatic standardization of such details.

It is clear that quite a number of these series belonging to the four fundamental groups should be alike. A certain connection between some of the series ought to exist. For example, the series for normal diameters, group 3, ought to include all of the numbers in groups 1 and 4 which are employed for the selection of diameters. The series for lengths, group 2, could easily be unrelated to other groups.

Most of the existing standardizing bodies have devised standard series for diameters. The purpose of these series is to reduce the number of gages for finished diameters to a minimum, but they are also applicable to rough diameters for the purpose of saving patterns.

Any standard series must evidently be devised so that it can be followed under all circumstances, and at the same time so that as many numbers as possible may be left out. Thus far the series for normal diameters that have been worked out in different countries are very similar. The general character of these series is that they contain all the whole numbers between 1 and 20, all numbers ending in 2, 4, 5, 6, 8, and 0 between 20 and 50, all numbers ending in 2, 5, 8, and 0 between 50 and 100, all numbers ending in 5 and 0 between 100 and 200, and all numbers ending in 0 between 200 and 500. In addition some of the series for normal diameters contain other numbers intended for special purposes. The Austrian, the Swiss, and the Swedish series contain the numbers 37 mm. and 47 mm., to be used only in connection with ball bearings, these numbers being internationally employed as outside diameters of ball bearings. The diameters in the S. I. thread system are generally inserted in the series, and some of these should be used only for this special purpose.

It has been stated above that the numbers between 20 and 50 in the series for normal diameters end in 2, 4, 5, 6, 8, and 0. This use of the intervals 1 and 2 makes the series seem somewhat irregular. Further, the part of the series between 50 and 100 has the intervals 2 and 3. These irregularities, however, are unavoidable, due to the fact that our ordinary series of numbers is based on the number 10 and that we prefer to use numbers ending in 0 in the first place, secondly, numbers ending in 5, and thirdly, all even numbers. Evidently the series for normal diameters would have been more uniform and comprised fewer dimensions if the number 8 had been chosen as the base instead of 10. The author is of the impression that in this event the English inch system would have been changed by this time. As it is now, that system has a practical advantage over the metric system in the fact that the number 12 has a greater divisibility than the number 10.

There are many who argue that the number 12 should be employed as the base, and recently in Germany a change of system has been discussed. However, any such change is inconceivable, and we shall have to make the best of the mistake our ancestors made when they selected the number 10, and put up with the resulting larger number of normal diameters and uneven intervals in the standard series. And what is more, we shall have to deal with two different systems for measurements, the metric and the inch system, for an interminable period.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

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29 West 39th Street, New York

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Editor and Teacher

ON AUGUST 29, 1923, Fred R. Low completed his thirty-fifth year as editor of *Power*. During this long period of continuous service, which has been marked by fine courage and broad vision, has come about the stupendous development and use of power which has made this country great. Fred Low has taught, encouraged, and analyzed, always good-naturedly, but with strength, and has built up a journal of unmistakable influence and value in an important field of mechanical engineering. A profession cannot be greater than its teachers, and Fred Low must be numbered among the great teachers of the engineering profession.

Fred Low's ideals of service have been demonstrated by the conscientious manner in which he has performed his duties on many important committees of The American Society of Mechanical Engineers. His election to the presidency is a fitting recognition of work well done and a presage of his activity in behalf of the Society for many years to come.

The Earthquake in Japan

THE gripping feeling at the heart that came when the first news of the terrible catastrophe in Japan was received, has not been relaxed by the later and more accurate reports of casualties and property losses. The people of Japan have suffered and the help and sympathy of the world have been extended to them. The relief fund in the United States quickly rose to millions of dollars.

The frequency of earthquakes in the Japanese islands has been emphasized by this event, and those of us living in more favored localities have been surprised to learn that throughout Japan earthquakes may average three a day. It is interesting to note, however, that man has partially succeeded in coping with their destructiveness and that buildings constructed by American engineers to withstand earthquakes in a large measure weathered the recent shocks safely.

The reports of occurrences during the earthquake and its resulting fire and pestilence, and the accounts of reconstruction efforts, testify to the courage of the Japanese people. Fortunately the major portion of the empire's industry seems to be unharmed, and its industrial and engineering leaders face the situation calmly and bravely with the ample resources they possess of brains and money.

Uncle Sam A-Flying

IN THE last few weeks there have been several developments indicating in a welcome manner the remarkable progress that has taken place since the armistice by the flying branch of the American military establishment.

The first flying tests of the Navy dirigible *ZR-1* were carried out with apparent satisfaction. The new dirigible embodies not only the aircraft lore acquired during the war by engineers of the German Zeppelin Company, one of whom acted as consulting engineer to the Navy, but also the vast amount of information, experimental and theoretical, in the hands of American authorities at McCook Field, the Bureau of Standards, the National Advisory Committee for Aeronautics, etc. Thus, for example, as was pointed out in the September issue of Mechanical Engineering, the *ZR-1* is the first dirigible in which the distribution of pressure over the surface of the hull is actually known and not merely guessed at.

Another development in the same field was the maneuver carried out by the Army Air Service for the purpose of demonstrating that any point on the Atlantic seacoast from Maine to Florida could be furnished protection by aircraft within not more than seven hours. It is to the credit of the War Department that means were found to accomplish this end, notwithstanding the comparatively meager appropriations granted to this branch of the Army since the armistice.

The battleship-bombing tests off Virginia may not have been as spectacular as those of 1921 when the ex-German battleship *Oestfriesland* was sunk by a single bomb, but they serve as a further proof of steady advance in the development of this new form of warfare. In the recent tests attempts were made to hit the battleships *Virginia* and *New Jersey* from considerable altitudes, 10,000 ft. down to 3000 ft., and while the percentage of hits was not high enough to arouse any special interest, the fact remains that both battleships were sunk with gratifying promptness. While the tests have not shown that the battleship is truly obsolete in view of the development of the bombing airplane, they have nevertheless shown that control of the air by an enemy may be, and probably already is, of the most vital adverse significance even to the most powerful surface-fleet units. In other words, the American tests may be considered as having established the fact that naval warfare is already warfare in the air as much as it is on and under the surface of the sea.

In an article which will appear in an early issue of Mechanical Engineering some additional sidelights will be presented on the development of aerial warfare in connection with the growth of the Chemical Service.

International Conference Promotes Standardization Procedures

THE value of international contact in standardization matters was demonstrated in the second unofficial conference of representatives of various national standardizing bodies held at Zurich, Switzerland, July 3–6, 1923, at which there were representatives from thirteen countries, Austria, Belgium, Canada, Czechoslovakia, France, Germany, Great Britain, Holland, Italy, Norway, Sweden, Switzerland, and the United States. The conference discussed the possibilities of better intercommunication between the various national standardizing bodies, the interchange of reports, the organization of international efforts, and the methods for the practical utilization of standardization work. Messrs. Zollinger (Switzerland) and Le Maistre (Great Britain) acted as president and vice-president, respectively. The American Engineering Standards Committee was represented by Dr. Paul G. Agnew and the Canadian Engineering Standards Association by C. J. Durley.

The most important subject before the Conference was the interchange of information on work in progress. The Conference was unanimous in the view that the two principal phases of international coöperation are very distinct and should always be so treated, viz.: (1) Interchange of information, and (2) negotiations to bring about international agreement, i.e., international standardization. A free interchange of information can be of the utmost value to each country in its own work, saving multiplication of standardization and investigation, and paving the way for international agreement.

While the recommendation of the London Conference in 1921 provided for quarterly interchange of information on the status of projects, these reports are limited to a mere statement of progress, and there has been no general understanding as to the interchange of drafts of standards and of information relating to them.

After most careful consideration the following resolution was passed by the Conference:

> The Unofficial Conference of Secretaries, having noted the important progress already made in the interchange of information regarding work in progress between the various national standardizing bodies, requests each Secretary to submit to his organization: (1) The great desirability of making such information available, on request, to all the national bodies for use in their own work. (2) The interchange of draft standards as and when submitted for public criticism.

It will be noted that the first recommendation contemplates interchange on request only, the opinion being that the amount of expense and work involved in a complete scheme of interchange makes such a plan impractical at the present time; hence the limitation of making the information available on request.

The second recommendation has to do with the interchange of drafts of standards at the time they are published for public criticism. There is every reason to believe that the various sponsors will be glad to furnish a sufficient number of such copies for transmission to the foreign bodies.

Difficulties have arisen in the translation of certain technical terms of importance in standardization work. It was agreed that whenever trouble is encountered with such words, agreement on the best possible translations into English, French and German shall be reached by the secretariats in English-speaking, French-speaking and German-speaking countries, respectively. In this the clearing-house work is to be done for the present by the Swiss secretariat (since Mr. Zollinger was president of the Conference). These decisions will be circulated to all of the national bodies, the corresponding terms in other languages being added by the respective secretariats when they desire to do so.

At the London Conference in 1921 it was the unanimous opinion that the time was not ripe for a formal international standardizing body. As a result, it was informally agreed that, pending further experience, the experiment called "working centers," should be tried. An example will make the meaning clear. The Belgian Association being one of the bodies most interested in specifications for zinc and zinc ores, and having proposed international agreement on the subject, it was agreed that the Belgian Secretary should assume the duties of a secretariat for this subject, as if he were the secretary of an international body for the purpose, but in a much less formal way.

To carry on the work of the Conference it was decided to request the president of the Conference to proceed as if he were the executive officer of a loose association.

The Swiss Standards Association, acting as hosts, made very complete arrangements for the comfort and entertainment of their guests. Visits to a number of manufacturing establishments were arranged and at the conclusion of the conference a two-day tour was arranged from Zurich to the Jungfraujoch.

Blended Fuels

Increasing attention is being paid to the subject of blended fuels, partly because of the possibility that some blend may be developed that will give increased power or engine efficiency, and partly also to relieve the ever-present threat of gasoline shortages in the future.

Professor Smallwood's investigation, published elsewhere in this issue, would seem to indicate, in general, that thus far the use of blended fuels has not led to any clear increase in the power developed by the engine, nor has it apparently produced any appreciable increased mileage per gallon, except with a heavily carbonized motor.

On the other hand, benzol is a smooth-burning fuel and when mixed with gasoline, even in comparatively small quantities, tends to suppress preignition knocks ("pinking"). Benzol also gives a somewhat better motor operation, so that blended fuel would appear to be worth perhaps two cents more per gallon than straight gasoline.

Tentative Program for First World Power Conference Is Announced

O. C. Merrill, Secretary of the United States Federal Power Commission, returned late in August from a meeting in London relative to the World Power Conference which is to be held in London during July, 1924. Mr. Merrill is general chairman for American participation in the conference to which over twenty American engineering, technical, and industrial organizations have indicated already that they will contribute.

The objects of the World Power Conference will be to consider how the industrial and scientific sources of power may be adjusted nationally and internationally. Those arranging the conference propose to achieve this purpose as follows:

1 By considering the potential resources of each country in hydroelectric power, oil, and minerals;

2 By comparing experiences in the development of scientific agriculture, irrigation, and transportation by land, water, and air;

3 By conferences of civil, electrical, mechanical, marine, and mining engineers, technical experts, and authorities on scientific and industrial research;

4 By consultations of the consumers of power and the manufacturers of the instruments of production;

5 By conferences on technical education to review the educational methods in different countries, and to consider means by which existing facilities may be improved;

6 By discussions on the financial and economic aspects of industry, nationally and internationally; and

7 By conferences on the possibility of establishing a Permanent World Bureau for the collection of data, the preparation of inventories of the world's resources, and the exchange of industrial and scientific information through appointed representatives in the various countries.

The tentative program which was agreed upon at the London conference has been announced. All the papers to be presented will be printed and distributed in advance so that the entire time of the delegates at the meetings may be devoted to discussion. It is planned to feature a concise statement of the existing power situation in each country and to discuss conditions under which capital of one country can be invested in utility enterprises of another. A decided effort will be made to make the conference especially helpful to the professional engineer.

The conference will be conducted under five divisions, namely, power resources, power production, power distribution, power utilization, and general. The first division, that on resources, will be of interest to the whole conference and will comprise for each country a general survey of national power resources, developed and undeveloped; investigation of national power resources; power resources available and utilized; administration of power resources; and electrical power markets.

The sections under the second division deal with water-power production, preparation of fuels, steam-power production, internal-combustion engines, and power from other sources, such as wind power.

The division of power transmission and distribution will cover alternating-current transmission and distribution, high-voltage direct-current generation, transmission and distribution, and low-voltage distribution and electrical storage.

There are to be four sections on the utilization of power, i.e., power in industry and domestic use, power in electrochemistry and electrometallurgy, power for transport, and power for lighting and illumination.

The general division comprises a number of subjects which are likely to be of primary interest at the conference but do not readily lend themselves to classification in the other divisions. In many cases they are merely special aspects of subjects in the other divisions. One section will deal with economic, financial, and legal matters, and the other include such items as research, standardization, education, health, publicity, international coöperation, and permanent organization.

The executive committee for American participation includes representatives of government departments, the four national engineering societies, and other engineering organizations.

Constructive Reforestation Legislation Imperative

IN A STATEMENT prepared for the guidance of the member societies of the Federated American Engineering Societies, Colonel William B. Greeley, Chief of the United States Bureau of Forestry, warns that the predicted timber famine has already overtaken the eastern and central sections of this country. His summary of the situation is, in part, as follows:

Originally the United States contained five trillion board feet of stumpage; now, only one trillion, six hundred billion feet of virgin timber and six hundred billion feet of culled and second growth remain. Timber is being cut or destroyed at the rate of sixty billion board feet per year. Soft wood is being cut eight times as fast as it is being replaced, and hard wood three times as fast. Seventy-five per cent of all timber being cut is not being replaced.

Transportation is the key to lumber supply. Removal of the timber supply from points of consumption because of transportation charges has created retail prices so high that many demands for lumber cannot be satisfied. Twenty-eight states produce less lumber than they consume. In the space of seven years the average lumber haul between sawmill and consumer has increased 34 per cent.

There is probably not a single wood-fabricating industry east of the Mississippi and Northern Ohio and Potomac Rivers which does not today use wood distinctly inferior in intrinsic quality to that used twenty years ago. There is necessity now for teaching a vastly needed lesson of economy and of adopting new woods to old uses.

Grading of lumber must cease to be a matter of custom and become a matter of science. The consuming public must be furnished with exact knowledge of quality and forms of service forest products can render. The United States consumes about two-fifths of the forest products manufactured in the world.

Our per capita consumption of paper and other materials made from wood fiber has increased from 30 to 149 pounds in forty years. It about doubles that of England, the nearest competitor. National habits in the use of wood will have to be changed; the question is how much social and economic suffering will this change involve and what can be done to alleviate it. The per capita consumption in other countries is increasing, not decreasing. The demands in the United States are not going to decrease.

Ninety-eight per cent of rural dwellings in the United States are made of lumber. One of the crying needs in some agricultural sections is for better homes and the higher living standards which depend largely upon better homes.

The manifest requirements of the situation are:

First, make the timber we have go as far as it will through reducing waste and improving the efficiency of its use.

Second, make progress as rapidly as possible toward a permanent and sustaining supply of timber by increasing the growth in woodlands and by putting idle acres to work growing trees.

To sum up, the economic and social losses involved and the rapid depletion of the forests of the United States are so large and far-reaching as to challenge the attention of our most profound thinkers, to the end that there may be a more comprehensive plan for the elimination of waste in the growth and utilization of forest products and for reforestation.

In a letter from Charles H. McDowell, chairman of the Reforestation Committee of the F.A.E.S., the purpose of this committee is stated as being to direct the attention of engineers in particular and the public in general to the present serious situation due to national and state delay in passing constructive, workable and non-political laws for afforestation and reforestation, and to interest them in securing prompt legislative action.

In reviewing the present status of affairs, Mr. McDowell says further:

Lands suitable for the growing of forest products are owned by governments, corporations and individuals. Timber is a slow-growing crop, and the carrying charge of government-owned forests is a small one. This is not true of privately owned replanted cutovers or other forest lands. Interest charges on land values over the many years of tree development is a large item of cost. When taxes and interest on taxes over this period are added, there is no encouragement for new tree planting by companies or individuals. Many European countries assess only a nominal tax on growing forests and wood lots, but collect a tax from the income as these forest products are marketed. In many cases they require replacing of trees cut.

The tax load prevents aggressive forest planting both by companies and by individuals. Laws properly framed to protect the public but granting substantial tax exemptions on growing timber will go far in encouraging new tree planting.

There are many forest questions and policies which engineers can well study and report on, as for example, the policy of further acquisition of forests by federal, state and local governments and their method of coöperation with private owners of timber tracts that head waters may be protected, erosion minimized, fire patrols extended, and drainage controlled. Forestry schools should be encouraged by adequate appropriations so that the production of men skilled in handling the problems of reforestation would meet the needs.

Better care of forests, less wasteful exploitation, a fuller utilization of forest raw materials, timber preservation, minimizing of fire and tree-pest losses, are of vital interest to engineers and to the public.

The personnel of the F.A.E.S. Reforestation Committee is as follows: Hugh K. Moore, technical director, Brown Co., Berlin, N. H.; Dr. C. E. Paul, Armour Institute of Technology, Chicago, Ill.; C. G. Adsit, 555 Electric and Gas Building, Atlanta, Ga.; J. C. Ralston, 2421 W. Mission St., Spokane, Wash.; George A. Reed, State Engineer, Montpelier, Vt.; Theodore W. Norcross, U. S. Forest Service, Washington, D. C.; Dr. Raphael Zon, U. S. Forest Service, Washington, D. C., C. H. McDowell, Chairman, 209 W. Jackson Boulevard, Chicago, Ill.

Coal-Storage Survey Nears Completion

MEMBERS of the F.A.E.S. Committee on Coal Storage met in Chicago on August 27 and 28 to collate reports on different phases of the work which they have been carrying on during the summer.

The loss due to weathering has frequently been given as an argument against coal storage. Dean S. W. Parr of the University of Illinois, a leading authority on the chemistry of coal, gave facts proving that coal suffers only a slight deterioration in calorific value by exposure to air. Twelve years' experience with coal storage at Urbana has shown him that even the most volatile of central Illinois bituminous coal can be stored with but little loss, if proper methods are employed.

Methods in dock and pier storage, other than "head-of-the-lake" storage, were described by O. P. Hood, chief engineer of the United States Bureau of Mines. His statement included a report on storage by the Federal Government, with specific references to the Army and Navy and the Panama Canal.

A report on Duluth and Superior storage, where the greatest and most efficient storage plants in the world are located, was made by W. H. Hoyt, chief engineer of the Duluth, Missabe & Western Railway. Many recommendations of the committee will be based upon methods employed at these plants, which during the last coal year stored approximately 12,000,000 tons of bituminous and 1,500,000 tons of anthracite coal.

Among other special reports presented were the following: Mine Storage Location, by W. J. Jenkins, vice-president of the Consolidated Coal Company, St. Louis; Economical Use of Stored Coal, by David Moffat Myers, consulting engineer, New York City; Development of Storage Possibilities in Chicago, by E. S. Nethercut, secretary of the Western Society of Engineers, Chicago; Anthracite Storage, by R. V. Norris, consulting engineer, Wilkes-barre, Pa.; and Items of Transportation, by Roy V. Wright, editor of *Railway Age*.

The coal-storage survey represents one of the biggest concerted efforts of engineers that has ever been made in this country. Over a hundred sub-committees were formed for making local studies in cities in every state in the Union. These committees, consisting for the most part of five members each, are composed of leading local engineers representing national and local engineering societies and the various branches of the engineering profession. Operators, railway officials, and distributors have coöperated with the engineers, enabling them to assemble detailed information on the production, distribution, marketing, and consumption of coal. So far as possible the work of the local committees has been systematized by the use of a standard outline for their procedure and a questionnaire for the solicitation of information from different industries.

Dean P. F. Walker, field executive of the committee, who has been in close contact with the work of these sub-committees in many of the principal industrial centers of the United States, reported widely varying conditions, necessitating in many cases individual study and processes for the solution of the problem. Dean Walker advocated the establishment of large coke plants in industrial centers which would provide a substitute for anthracite and also supply cheaper gas for such communities. This plan would greatly facilitate storage, since coke is safe from spontaneous combustion, and would be of great value to the small consumer, especially the domestic consumer.

Before completing the survey another meeting of the committee will be held, probably in Washington. It is expected that all material for the report will be ready by December 1, and that the report will be released for publication early in 1924.

Phases of Industrial Management

Problems Confronting Executives in the Carrying On of Constructive and Productive Operations—The Qualifications of a Manager—The Financial and Business Side of Management

THE following twelve brief articles are extracts from papers presented at meetings of Local Sections of the A.S.M.E. held throughout the country during Management Week, October 16 to 21, 1922. They may be divided into three general groups, the first taking up the problems that confront an executive in the carrying on of constructive and productive operations, including the side of management having to do with human relations; the second dealing with the qualifications of a manager and requisites for success in management work; while the third concerns itself with the business and financial side of management.

Problems That Confront an Executive

Fundamentals an Executive Must Consider[1]

AN ENTERPRISE divides itself broadly into the following heads:

1 Engineering, in which is initiated the idea underlying the product, the scheme of the product itself, and the methods of making it.

2 Production, which deals with the actual work, the machines, and processes capable of turning out the product multiplied many times. Into this begins to enter the element of cost, for it must be considered not only how the production can be turned out, but how cheaply.

3 Sales. When the product is made, how can it be sold? This problem, which used to be left not so very long ago to the haphazard dealings of the loudmouthed, free-mixing salesman, is now rapidly becoming a question of scientific research. Modern merchandizing methods are not always founded on sociability, but they are founded on a close study of the needs of the community, and the problems of distribution are very many and very serious.

4 Labor Problems. Curiously, these have become in the last few years totally distinct from production problems. We are beginning to realize more than ever that we have a duty to labor. The old patriarchal idea which Carlyle writes about, and which obtained approximately during the middle of the last century, was that the workmen were children and the employer was a benevolent father who looked after them and provided them with the wherewithal; the children, however, had to do as they were told. Nowadays labor is demanding a partnership. The discussion is one that will go on for some years yet, but labor has to be dealt with each day on a newer plane.

5 Costs and Accounting. This is no mean problem: How shall we apportion our overheads? What does it cost to get the business? What does it cost to do the business? Are we getting enough for our product? How little can we take the business at and make a profit? And if we exceed that little, can we get the business?

6 Finance. This problem deals with the raising of the necessary money to start the business, to purchase the necessary workshop, the necessary tools, equipment, etc., to pay for the necessary help, the ever-pressing problem of the next payroll, the question of having bills paid promptly, and of receiving money promptly.

These are the six main problems that confront the present executive. Perhaps his biggest problem is to choose lieutenants who will operate in each of those divisions successfully, satisfactorily, relieving him of the responsibility to a large extent, and yet being able to keep him in touch with what goes on so that he can correlate their various activities and build up what is known as an organization. An organization is the human machine which through a process of time has demonstrated its ability to function smoothly and efficiently. The men forming the organization, while working as units, dovetail into one another harmoniously so that without conscious effort they understand not only their own position but their position relative to the whole organization.

Do I need to tell you that in each of these activities there are all kinds of details into which at times the manager is called upon to go? He must act many times as a judge, weighing evidence this way or that way, giving decisions which, like a judge, he must live up to in order to be respected, and in all ways try to be fair. It is unnecessary for him to have an intimate knowledge of each of those subjects, but he should have sufficient knowledge to be able to understand the problems of each department and to be able to reason intelligently with them to discuss them and to give decisions. It is necessary, therefore, for him to have a knowledge of what might be called the "fundamentals" of this work.

[1] John Younger, Mem. A.S.M.E., in a talk to students of Ohio State University.

Carrying On Constructive and Productive Operations[2]

IN THE BUILDING of the constructive organization we have the problems of selecting the men, the problems of assembling and handling the materials, and the problems of determining definitely and conclusively what is to be accomplished.

We are concerned with a plant in any particular industry, its arrangement, the character of its equipment, the sequence, or order, of departmental operations, the arrangement of departments as related one to the other, the capacity of departments as related one to the other, and the location of the plant and its facilities for handling materials to and from the plant.

In the constructive as well as the productive organization we have to select the men best suited to each job and so arrange them that the product of one man's labor fits in with that of another, to the end that the best results from labor are obtained.

The arrangement of these men involves careful study with respect to grouping the men with their foremen or directing heads in charge of them. The making of the product has to be properly supervised and the work properly directed from day to day from the highest directing officer down to the lowest foreman in the organization.

From these necessities in connection with constructive and productive organizations, we can at once see that the management has three distinct functions to perform: It must first analyze the work it has undertaken to accomplish. It must then organize to carry it out, and must continue to direct and supervise the organization when built. We therefore have three functions of management—to analyze, to organize, and to direct.

Analysis of constructive and productive work is a most important function of management. The scheme of any industry as a whole must be taken apart and reduced to its simplest terms. We must determine definitely what we wish to do, what is to be accomplished, what is to be produced. Such analysis usually takes the form of putting on paper plans of the plant, showing in a general way the location of the necessary equipment, the arrangement of the plant, railroad tracks, and whatever other facilities may be needed in connection with it.

Having arrived at the point where analysis has enabled us to reach a definite decision in the matter of plans, we are now concerned in the organization to carry our plans through.

The building of an organization requires as much thought and as much time and study as does the planning; and, if neglected, may lead to excessive costs.

The directing head of an industry properly exercises full and complete control over all men in the organization, the results of whose activities he is responsible for. He has his assistants reporting directly to him and he issues his instruction through them. These assistants in turn direct superintendents in charge of departments, and superintendents report directly back to the assistants.

A superintendent of a department has his various general and sub-foremen. He properly issues his instructions to his general foremen and they in turn report directly to him, and the general

[2] H. C. Ryding, Mem. A.S.M.E., in a paper read at a joint meeting of Electrical, Mechanical, and Civil Engineers in Birmingham, Ala.

foremen in turn issue their instructions to the sub-foremen, and the sub-foremen report directly to the general foremen.

An organization, therefore, is made up of a directing head, the assistants to a directing head, the superintendents reporting to an assistant directing head, general foremen reporting to a superintendent, and sub-foremen reporting to a general foreman.

The plan of this organization follows very closely the basis of a first-class military organization, and its procedure is also practically the same.

In the matter of instructions, no superior officer can afford to give a workman instructions other than through his foreman or superintendent. If he should do so, he relieves the foreman or superintendent, in whose department the workman is engaged, of all responsibility for carrying out the instructions given by him to the men. There is nothing that destroys discipline in an organization so quickly; and, as I have often said in discussing this subject with men interested in the question of organization, any fool can come in and break up an organization, whereas it takes a real man to build one up and maintain it properly.

In the maintenance of an organization, and presupposing that the best has been done to select men best fitted for the jobs, it is important that a well-defined scheme of promotion be established and understood, in a general way at least, by all subordinate officers. There is nothing that so encourages a man to do his best for you as to know that his efforts will be appreciated, and that appreciation is best shown by promotion when the opportunity offers.

A fair scale of wages is also a fundamental, and must at all times be thoroughly understood by all directing heads in any industrial organization.

Accuracy in timekeeping, accuracy in maintaining the individual rates in a wage schedule, is work of the highest importance and should properly be done at all times by men familiar with this particular class of work.

The pocketbook of the workman is his tenderest spot, and any touch there is very quickly responded to.

In directing the activities of an industry, simple and complex questions arise daily. Such questions may involve treatment of men, promotion of men, dissatisfaction on the part of an employee, and many others concerning the rate of operation or the inefficiency of perhaps a certain individual and inability of a department to turn out the product that it should turn out, and react unfavorably upon other departments.

All such questions must be carefully considered by the directing head of the activities of an industry. He should properly analyze the difficulties and when a conclusion is reached his instructions, in so far as it is possible, should be conclusive. I have often thought that inconclusiveness on the part of directing heads is one of the faults to which we do not give enough attention. Time is saved not only by the directing head but by the workmen when positive and conclusive instructions are given by the directing head.

If a matter can be settled at once, it is better to do so than to let it lie over, say, a couple of days before giving your answer.

Management and the Human Factor[3]

WHAT in brief has management to do? Successful management must satisfy the public, capital, and labor.

The Public desires five things in industry:

1 Stability
2 Adequate goods and services
3 Competent leadership
4 Some control in emergencies
5 Progress.

Capital desires the same five things in terms of:

1 Security of investment
2 Adequate production
3 Good management
4 Sufficient control of conditions affecting the risk
5 Expansion.

Labor's desires are very similar to the above, and obviously can only be obtained if the results desired by the public and capital are forthcoming. They are:

1 Steady employment
2 Adequate real wages
3 A good foreman
4 Individual and collective voice about conditions
5 A chance to rise.

If coöperation is possible, is the attainment of it probable? We believe that a large measure of benefit to the public and capital will accrue through seeing that the worker obtains in a satisfactory measure the five things just mentioned, and that he does so through democratic processes. We do not believe that these ends are inconsistent with those of the public and capital, for the latter at its best is just enlightened management, and with its industrial engineers it must answer satisfactorily this question: How are the masses of men and women, both without and with capital, to be taught to labor with their hands and brains willingly and efficiently that they may secure out of the products of their toil and their thought what they feel to be, and what will be in fact, a fair return?

Adequate incentive in professional opportunity and salary, and sometimes a possibility of a share in profit, must be forthcoming to secure the full services of the best ability both of direction and technique. Assumptions that the wheels of industrial direction can revolve solely under altruistic and "other-regarding" motives are vain. Such reformers should concentrate first of all upon human nature.

In the case of the wage earner, to remove the nightmare of unemployment from the workman's pillow; to carry any necessary surplus of labor of an industry at that industry's expense; to pay the highest possible wages; to improve the economic machine to that end; to lead, not drive, men by adequately trained and sympathetic executives who will command their respect and esteem; to provide for self-expression on all of the worker's interests and to keep the way open for his education and advancement and responsible participation; are measures both just and necessary and should be the basis of all industrial relations in coöperative industry.

The Psychology of the Situation. The nature of the relations between capital and labor as a whole at any time is determined by the quality of the relations between the individual employers and their wage earners. It is largely dependent upon their feelings about each other—is conditioned by a state of mind which arises out of the declared objectives of these two groups of human beings, and out of the moral and economic qualities of their intentions and conduct toward each other and toward society at large. This conclusion is the settled conviction of those who have come to know the workers and who spend their days in responsible direction of industry.

The Information Needed. Any helpful study must be more than descriptive. It must be practical and suggestive. It must not only uncover error, correct misunderstanding, and expose the vulnerable joints in our social armor—there are some people doing the latter without understanding and some with unhelpful intentions today—but it must reveal their true causes and, if possible, it must substitute constructive relations around common objectives.

It must analyze and measure—at least approximately—the feelings and conduct of labor and capital about all matters arising out of the employment relation. Unless this is done, unqualified statements on the subject, which are too common, lead to generalizations and assumptions about it which are not warranted, and to programs which give little help in the premises.

The Instruments of Capital. As we have seen, to make goods plentiful and men dear is calculated to satisfy the desires of the public, capital, and labor. In setting forth in some detail how management can best coöperate to this end and in the plant, the consideration of what capital should provide for this purpose is first in order. Adequate production under capitalism involves suitable means, material, and men, in well-balanced coördination with skillful direction, and operating under the conditions and incentives which secure a happy response from all concerned in the endeavor.

Workers are quick to sense the absence or existence of brainy, helpful provisions in equipment, system, and management for making the day's work expeditious, fruitful, and less fatiguing.

[3] John Calder, Mem. A.S.M.E., in a paper read at a meeting of the Chicago Local Section.

The Key Position of the Foreman. Assuming the existence of a good plant, the assistance of good planning for production, job analysis, time study, and all research essential to discovering the best about what can be done, where it can be done, how it can be done and by whom, we may ask what more in the premises management can do about organizing production among its own human factors.

The answer is that the moral, mental, and technical abilities of the non-commissioned officers of industry—the foremen, the men in front, the men next to the men who "deliver the goods"—should receive especial attention. In fact, too much emphasis can hardly be laid upon the necessity for raising the quality and performance of all supervision. Capitalism, however enlightened and progressive in intention and policy, must multiply itself through its minor executives who make the actual contacts with the employees. There is no other way, and there is no short cut even by this way.

Usually with fair technical competence, though often none too much, foremen—so far as being selected for executive ability is concerned—frequently "just happen," and when the date of the accession of the weaker ones to such a position is somewhat ancient and nothing has been done meantime to qualify them psychologically and in a humanitarian way for the job, the employer has "wished upon" himself, usually permanently, the incubus of the modern plant, namely, the "hard-boiled" executive. He is not always a foreman. The higher up he is the more harm he can do and the harder he is to reform. Too great stress cannot be laid upon the selection of executives and true measurement of their qualities and reasonable measures for developing their abilities. In the writer's belief this is much neglected in the case of the immediate supervisors of the workmen.

There are three principal ways of developing the foremen otherwise than as a technician:

1 Foremen training for production, with stress upon handling the human factors
2 Foremen training as interpreters of capital's industrial-relations policy
3 Foremen training as management representatives in councils.

Qualifications of a Manager—Requisites for Success in Management Work

Characteristics of the Successful Manager[4]

The first of the qualifications which a successful manager should have is personality, three qualities of which are to be stressed, namely, (1) authority which springs naturally from a thorough knowledge of the jobs obtained through education, (2) physical and mental ambition and enthusiasm, and (3) affirmative assertiveness.

The second characteristic is the ability to judge men and their individual capacities. The third is patience and sympathy expressed through a willingness to receive employees and discuss their problems.

Fourth, the successful manager must be analytic and synthetic, with the ability to thoroughly analyze and organize his business into proper functions and departments. It is to be emphasized that the business must be organized on a progressive promotional basis so that each employee can see that by meeting certain standards, opportunity for promotion is ever present. This involves a definite training program so that every employee may grow in proportion to the time he remains with the organization.

The next qualification is the ability to create an *esprit de corps* in the entire organization. One factor in effecting coöperation is the taking of some interest in employees other than a purely factory or business interest. This can be done by means of a welfare program.

The last characteristic—and a very important one— is sincerity, without which failure is imminent. The manager is the source from which the organization draws its ideals.

[4] W. W. McLaureine, Professor Industrial Education, Georgia School of Technology, in a paper read before the Atlanta Local Section.

Requisites for Success in Management Work[5]

My observation tells me—and when I am telling you this it may be an unkind truth, but I am speaking of my intimate knowledge of men as a class, though there are exceptions, of course, to every rule—the average engineer lacks aggressiveness; he lacks in contact with the business world; he lacks positiveness and the ability to face the man of aggressiveness. This lack, I imagine, comes of his burning the midnight oil and his concentration of thought upon the greater things of engineering. I have seen engineers come before executive officers, filled with the best of ideas, with splendid thought and intent upon problems that they desire to have the management solve for them, who melt away and disappear because of the cross-questioning and the inquisitive minds of the men in charge of the organizations who must know for themselves exactly what is in those engineers' minds. There is not generally a comprehension in the mind of the engineer of the soundness of his own doctrine. He is not certain of himself. Management is nothing more nor less than certainty, absolute determination, and absolute knowledge and discrimination—intuitive, perhaps—of right or wrong. The man occupying an executive position must be one who can say yes or no to problems submitted to him without wavering or without showing any uncertainty. If he is dealing with engineering problems he must of necessity have an intimate knowledge of such problems; not, however, to the extent of being able to work them out but having an understanding of them, or else he should not occupy a position that brings him into contact with engineers. Because of the lack of aggressiveness and of positiveness engineers do not as a rule rise to those positions where they can command others.

Management consists in securing and retaining the love and affection of the men in the organization and their trustfulness in those superior to them. And yet there is no superiority in a real organization or in a company properly managed. All in it are on a level. Of course, some one man must at some time or other give the deciding voice on problems or policies, but when it comes to the particular duty of each part of the organization—I know whereof I speak, and some of my men here will confirm everything I say—they are taken into the confidences of the man who for the time being has a higher position, and they are listened to; they are allowed their voice, and very often allowed to make the decision in matters of importance. And above all, the thing that makes for successful management and successful organization is the trust that is reposed in those in power by the men below them in the line. There must be no jealousy or no feeling in the mind of any one of the men that some one else in the organization is getting the better of a position or a situation, or preferment in any way; and if you throw out jealousy and substitute loyalty, you have in my judgment a perfect organization, and perfect management.

Now, I am going to suggest to you engineers here tonight that if you expect to succeed in management, if you expect to get out of the groove in your chosen profession, if you are ambitious to rise to the top so that you may control men and things and events, you must throw off the restraint that holds you in its grasp. You must be ready and able to argue the questions that you believe in with those who doubt them. You must be ready to receive reproofs and rebuffs to the things that are nearest and dearest to your hearts, or the things that you think ought to be most considered and best considered by those to whom you are responsible. You must help the other fellow alongside of you, to pull him up if he is down, to raise him a little higher if he is deserving of it in your estimation. It is all human nature after all. Engineers are no better than nor different from any other class of men that I know, except that they have keener minds and greater vision. They are doers of things, they have their accomplishments. And by that they too often submerge themselves, because an engineer must be an artist to be a true engineer, and an artistic temperament is not combined with management or executive control. No man in that position can be an opera singer. He must have a tight jaw, a keen eye, and a decisive mind. Unfortunately, as a rule engineers do not possess those requisites unless schooled to them, or unless they possess a determination to succeed in that particular line.

[5] John A. Britton, Mem. A.S.M.E. (deceased), in an address delivered before the San Francisco Local Section.

Shortcomings of Certain Engineers in Management Work[6]

IT IS NO REFLECTION to recognize that many of the engineers that followed in the trail of such pioneers as Taylor and Gantt have failed in the fulfillment of their claims. Their chief weakness has lain in:

a Too great a generalization
b A lack of appreciation of "inertia" in human enterprises
c A lack of appreciation of the human element
d A lack of understanding of executive viewpoint
e A lack of knowledge of selling methods.

The chief error on the part of these engineers has been that they endeavored to reconstruct industry quickly by revolutionary methods in place of recognizing that the slower evolutionary method was the path by which the greatest progress would be made. There is a healthy index in the endeavor on the part of engineers through special study courses to attain a better understanding of business enterprise. The engineer has been unusually weak in that direction. His business equipment has been very close to the vanishing point, and as a consequence he has ignored the selling side, the financial side, and the human side of business enterprise.

The engineer's method of working from data in place of more or less indiscriminate observation is taking root, and it may be pointed out that there is no one better prepared as a whole to use data than the engineer, who, from the very beginning of his training is accustomed to acquiring data, analyzing data, and interpreting data.

The Business and Financial Side of Management

Deflation of Values in the Machine-Tool Industry[7]

In periods of great activity, and even under opposite conditions, it is always advisable to build machines in lots so as to get the benefit of quantity production. This may involve tying up considerable capital. It seems to me, however, that a plant must be very poorly managed if the gains due to quantity production do not more than balance the interest charges on the extra capital required to finance the larger inventory. Of course when deflation is quite drastic and when large stocks are carried, losses are inevitable, just as large profits result from this policy on a rising market. It is therefore apparent that no matter how scientifically the actual manufacturing operations are managed, the judgment to determine when to carry large inventories and when to reduce them as soon as possible will have more bearing on the ultimate success of the institution than scientific management may have had during periods of normal or greater acitivity.

The Retailer's Point of View[8]

TAKE the store that did the normal thing when prices were rising and manufacturers' representatives who visited the store said, "This is fine, this is a sellers' market....." This particular retailer placed orders for far more goods than he could possibly use, started pyramiding his orders; transportation facilities began to break down, for the railroads could not furnish cars. When the change in commodity prices started to come he found he had bought far beyond his needs and began to cancel orders. He was calling upon bank credit and straining it. He was calling upon manufacturers and wholesalers to furnish funds for his financing. He cut down his inventory prices—he had to clear out his stocks before he could buy more merchandise—and came to the bottom safe enough, because he didn't go bankrupt, but without cash and with a great fear of purchasing more goods, with the result that at the bottom he was buying from hand to mouth, when prices were low. He made no money but lost a great deal in trying to liquidate the large inventory which he had on hand.

Another store had a normal purchasing power of 35 per cent of the next season's demands of its departments. When prices began rising, they thought 35 per cent was too much, that prices were away out of line and could not continue. They began cutting down instead of increasing, first to 30 per cent and then to only 25 per cent, and started buying from hand to mouth. Instructions were issued that no order for more than $5 was to be given unless approved by the merchandise manager. When prices started to break they found that they had a comparatively small stock on hand. They took advantage of every price change during the decline, turned their merchandise rapidly, and made a small profit upon every turn. They increased sales because the public was looking for lower-priced merchandise, not less. When prices reached the bottom point, in the fall and winter of 1921, they bought 60 to 70 per cent of their business' demands..... Although there has been much criticism of the practice, I believe it is a wise thing to take profit upon replacement values rather than on costs.

The questions raised are, first, the statement that it is inevitable that the retailer must take losses; and second, if that is the case, how soon must it be after prices start to decline; third, that it is good business to take a mark-up on replacement value rather than cost on rising markets, and also good business to take losses..... The way in which the retailer can help most is by abandoning his normal buying habits and purchasing from hand to mouth as prices advance—when the tendency is to overstock and pyramid orders—and by buying more heavily—but not speculating—at the bottom of the price level when business needs the orders. If he does this he will relieve the strain of merchandise credits, will stop cancellations to a great extent, and in that way eliminate change of price levels. To do this he needs the aid of manufacturers, engineers, and others, and those individuals will find it to their particular advantage to reach a more conservative program... It is a question to know when and how prices are going to change... Retailers should start studying the relation of commodity prices to retail prices, the relation of raw-material prices to prices at retail.

Management and Sales Policies[9]

A SALES PROGRAM must be entirely dependent upon the management policy, to my mind. During a period like the present it is not a question of how much you can possibly sell, it is how much you can save yourselves. It has therefore been our policy to find out first of all how much merchandise we could safely dispose of and then try to confine our merchandise to the channels which were most loyal and most attractive so that we could give service through those channels. Our program, therefore, has not been one of seeking new customers, nor one of seeking new products to manufacture. It has been one of keeping the business of those customers whom we could serve during this period. During the slump to come some time in the next four years our program will be directly the reverse of this. Then we shall seek new customers, shall seek a new product and a new market for our goods.

The Relation of Bank Credits to the Business Cycle[10]

INITIAL EXPANSION in the first of a period of activity does not demand credit. It does not go on very far before it becomes necessary for business concerns, if they are to buy goods at rising prices, to secure additional credit. It was the granting of more credit that made possible the further upward movement of wool..... Is there any way of moderating bank credits? Not by means of legislation, because that would involve restrictions of banking activities. It has been proposed that some change be made in the currency standard, some adjustment in the weight and value of our gold unit to offset changes in price. That is very doubtful wisdom and will probably not appeal to the general intelligence..... Federal bank credits are too late to be effective. We must look to the policies in general of the commercial banks of the large cities, for they give the tone to the whole situation.....

Banks provide a portion of the working capital of most business concerns—they limit their appropriation, they determine what they regard as safe limits. Along with other items of information they secure balance sheets and income statements from business

[6] Max Slovsky, in a discussion of L. P. Alford's paper on Ten Years' Progress in Management at a meeting of the Tri-Cities Local Section, Davenport, Iowa.

[7] E. A. Muller, Mem. A.S.M.E., at a meeting of the Cincinnati Local Section.

[8] Prof. Donald K. David, of the Harvard Graduate School of Business Administration, in a paper before the Boston Local Section, at Cambridge, Mass.

[9] Howard Coonley, Mem. A.S.M.E., in a talk at the Cambridge meeting of the Boston Local Section.

[10] Prof. O. M. Sprague, of the Harvard Graduate School of Business Administration, at the Cambridge meeting of the Boston Local Section.

concerns, and determine a safe ratio, namely, that the inventory, receivables, and cash shall be twice the amount of the current liabilities. In some lines a smaller proportion will do; in others the bankers think the proportion should be higher..... My proposition is that in periods of activity and rising prices a banker should insist, or at least strongly advise, that his borrowing customers improve their ratio, and if during a period of business activity in a particular case a ratio of 2 to 1 is considered quite satisfactory, then he should try to convince the customer that after two or three years of rising prices a ratio of 3 to 1 would be none too large to secure the same degree of business stability and advise him to curtail and build up this ratio; in each year of good profits to furnish from his own resources a little more of the working capital of the business and rely less upon credits of one sort or another, even the banks. Prices would rise slower because houses would have less funds if credits were curtailed..... I cannot measure the effect of the adoption of such a policy, but I believe it would serve in more than one way to moderate conditions, and would be infinitely better than keeping going up to the last minute and then trying to "get out from under."

THE FINANCIAL STATEMENT AS A BASIS FOR EXTENDING CREDIT[11]

FINANCIAL STATEMENTS have not been, and never should be, the only basis for credit. They should not enter into the situation more than $33\frac{1}{3}$ per cent; the other $66\frac{2}{3}$ per cent should be made up of character, ability, knowledge of the business, experience, condition of plant, nature of line, prospects, etc..... Banks should insist on statements more than once a year, say, every three months or six months. An actual example of the disadvantage of having statements only once a year is that of a textile-manufacturing company which had quick assets and current liabilities in the ratio of 1.52 in 1916; 1.62 in 1917; 2.62 in 1918; 4.09 in 1919; 5.07 in 1920; in 1921 had 99 cents to pay every dollar of indebtedness and in 1922 but 72 cents. During the years 1916 to 1920 the net worth of the company was in excess of the total indebtedness in the ratio of 1.41; 1.42; 2.15; 2.82 and 4.55, indicating with an increase in the net quick assets a steady and heavy growth all along the line. In 1921 the statements showed 2.23 of debt for every dollar the company had in the business, and this has since gone to $4.94. It is therefore believed that it would be advisable for all bankers to insist upon more frequent statements from borrowers.

LABOR SHORTAGE, NOT CREDIT STRINGENCY, WILL CHECK PROSPERITY[12]

WHAT is going to stop prosperity this time? Nor a stringency of credit, because this time our financial situation is utterly different from what it has ever been before in the history of this or any other country. The banks have ample loanable funds and are glad to make loans. They hold in their portfolios an amount of investments such as they have never known before and those investments can be turned into loanable funds on very short notice. In our Federal Reserve System we have a large part of all the gold of the world, and no country ever had the basis of such enormous credit expansion as there could be in America at the present time. So a lack of funds isn't going to stop this upturn, but it will probably come to a halt when American industries begin actively to compete with each other for labor. A labor shortage complicated by a shortage of railroad transportation—and the shortage of railroad transportation is already becoming serious—is beginning to show itself.

Now when these great up-turns or down-turns happen, very important changes take place in the mental attitude of labor. When prosperity is booming along, men rarely work as hard as they did before, but when a decline sets in they work much harder. That is one of those intangible elements in the problems of management that is of the very first importance.

In Akron in 1920 the average output of the automobile tire factories was substantially one tire per man per day. In 1921, with the same workers, the same factories, the same processes and same tires, the average output was 2.4 tires per man per day. In Detroit, in 1920, at the works of the Ford Motor Co., it took fifteen men working a day to make one car. In 1921, with the same machines, the same factory and the same men, eight men working a day made a car.

We are not yet able to avoid these swings. We are not going to be able to avoid them fully. We can mitigate them more and more as time goes on by finding out the facts by the scientific method, which, if I had to define it, I should say consists of analytical scrutiny, exact measuring, careful recording, and judgment on the basis of observed facts.

[11] F. S. Hughes, Manager Credit Dept., Federal Reserve Bank of Boston, in a paper read at the Cambridge meeting of the Boston Local Section.

[12] Colonel Ayres, Vice-President of the Cleveland Trust Bank, in an address at a meeting of the Cleveland Local Section.

A.S.M.E. Annual Meeting December 3-6, 1923

DECEMBER 3 to 6 are the dates for the coming Annual Meeting of the A.S.M.E. The plans for the technical program which are being developed by the Professional Divisions of the Society in coöperation with the Meetings Committee indicate a meeting that will be of great value to the entire membership. In the field of power there will be three sessions, one devoted to heat balance and boiler-room economy, one on methods of water-flow measurement, and one on the various phases of coal storage. A joint meeting with The American Society of Refrigerating Engineers will discuss heat transfer, cooling towers, and insulation for refrigerating cars. The Machine Shop Practice Division is planning to discuss the principles of sheet-metal working. A research report in the machine-tool field will also be presented. Textile mechanical engineers will be treated to papers on steam distribution and woolen-mill construction; the Gas Power Session will deal with heavy oil engines; the Railroad Division will discuss steel car design and operation and the Aeronautic Session will treat the technical problems of commercial flying. The Ordnance Division has secured the coöperation of the technical staff of the U. S. Ordnance Department and two interesting papers are promised dealing with the advance in physical research in ordnance and the production of ordnance steel. The Management Division is planning two sessions, one devoted to the importance of good engineering as a preliminary step to the development of good management and a second on the subject of management in the public interest.

The *A.S.M.E. News* will contain complete information about plans for the meeting as they develop and members of the A.S.M.E. must read the *News* to get this information as no special circulars will be sent out this year. The complete program for the meeting will appear in the *A.S.M.E. News* for November 22.

The plans for the meeting have been under consideration for several months and all papers are expected to be in the hands of the Committee by October 1, so that proper steps may be taken for their publication previous to the meeting. The great value of a technical meeting lies in the discussion at the meeting and it is the ambition of the Committee on Meetings and Program to have papers issued so that all members may have an opportunity to prepare carefully considered discussions. Owing to the reduction in appropriations this year, all meeting papers cannot appear in Transactions in full, and concise, well-prepared discussions will aid the Meetings Committee in the conduct of the meeting and the Publications Committee in selecting material for Transactions.

The second Exposition of Power and Mechanical Engineering will parallel the meeting and last out the entire week. It is hoped that this arrangement will give the members of the Society a better opportunity to view the interesting exhibits at the Exposition. As the Exposition opens at noon each day, the Committee on Meetings is arranging to hold the sessions of interest to power engineers in the morning. The Exposition management has announced that already space of the entire first floor of the Grand Central Palace has been engaged and the exhibition space will therefore be extended to include the mezzanine floor. A division devoted to power transmission has been added to the Exposition.

The first exposition drew an attendance of 47,580 representative engineers, operating men, executives and financiers as well as technical students and their instructors, and the expressions of interest on the part of those attending and the words of satisfaction of those exhibiting were but a small measure of the success of the exhibition in informing the engineering public of the latest developments in the art of generating and utilizing power. The second show, with its greater size and diversity will undoubtedly be of greater value.

Engineering and Industrial Standardization

A.E.S.C. Approves Specifications for Wrought-Iron Bars and Plates

THE American Society for Testing Materials, in submitting their standard Specifications for Staybolt, Engine-Bolt and Extra Refined Wrought-Iron Bars, A84-21, for Refined Wrought-Iron Bars, A41-18, and for Wrought-Iron Plates, A42-18, state that the preparation of these date from 1905 to 1913, the first work in this field having been done on the first-named group of materials in 1905. The specifications for staybolt iron remained tentative for five years. In 1910 they were revised and adopted as standard by the society. In 1912 the requirements for strength, elongation, and reduction of area were slightly raised, and a new section on each test was included. The addition of a suitable vibratory requirement for staybolt iron has not yet been possible on account of the impossibility of formulating a standard method of test that could be adhered to strictly on any two existing types of testing machines. In 1917 the specifications for staybolt iron were revised extensively; in 1920 a revision was made in regard to the permissible variation in diameter, which was adopted as standard in 1921. The first specifications for engine-bolt iron were adopted in 1912, and, after a number of revisions, adopted in their revised form as standards of the A.S.T.M. in 1921. The tentative specifications for extra refined wrought-iron bars were developed in 1919, being designed to cover large rectangular bars used in the construction of locomotives and for similar purposes. These were adopted as standard by the A.S.T.M. in 1921, in which year the three sets of specifications for staybolt iron, engine-bolt iron, and extra refined wrought-iron bars were consolidated under the title given above.

The specifications for refined wrought-iron bars were first written in 1912, by the A.S.T.M. Committee A-2 on wrought-iron, being intended to cover a grade of iron suitable for general forging, smithing, and construction purposes. Following their adoption as standard, a number of revisions were made, and they were again adopted by the society in 1921.

The specifications for wrought-iron plates date back to 1913. Two classes of iron are provided for, in both of which it is specified that the material shall be free from any admixture of steel. The specifications stood without revision until 1918, when minor modifications were made. They have since been adopted as a standard of the society.

The special committee which recommended to the A.E.S.C. approval of these three sets of specifications as Tentative American Standards was headed by Col. E. C. Peck, representative of The American Society of Mechanical Engineers on the A.E.S.C. In addition the committee included representatives of the following organizations:

American Marine Association, Shipbuilding Standardization Committee
Department of Commerce
American Institute of Mining and Metallurgical Engineers
U. S. Navy, Bureaus of Engineers and of Construction and Repair
Association of American Steel Manufacturers
American Society for Testing Materials
Society of Naval Architects and Marine Engineers

This committee further recommended that the American Society for Testing Materials should be designated sponsor, under A.E.S.C. procedure, for the future development and revision of these specifications.

Twelfth Annual Safety Congress Meets in Buffalo Next Month

THE safety congress which is called each year by the National Safety Council will be held this time at the Hotel Statler, Buffalo, N. Y., October 1 to 5. The first edition of the program indicates that twenty-four of the N.S.C.'s sections will hold one or more sessions. Among these are the Automotive, Chemical, Cement, Construction, Education, Electric Railway, Engineering, Ice and Refrigeration, Marine, Metals, Mining, Packers and Tanners, Paper and Pulp, Petroleum, Public Safety, Public Utilities, Rubber, Steam Railroad, Textile and Woodworking. Under each of these heads two or more papers will be presented and discussed by leaders in the safety movement.

Two joint sessions are scheduled, one with the American Association of Industrial Physicians and Surgeons, and the other with the New York State Department of Labor.

LIBRARY NOTES AND BOOK REVIEWS

Bibliographies on Hydraulic and Wave Transmission

IN hydraulic transmission power is transmitted by a continuous flow of the liquid, while in wave transmission the liquid pulsates backward and forward about a mean position. Because of this distinction the references on the two systems are given separately, but in one or two cases, indicated by the title, both systems are discussed in the same article.

This list of references was compiled by Elizabeth Seymour, of the Engineering Societies Library. The articles are on file in the Library, which will supply photostatic copies of them at the rate of twenty-five cents a page.

HYDRAULIC TRANSMISSION

A New System of Hydraulic-Transmission, A. Raudot. Revue générale de l'Electricité, vol. 9, 1921, pp. 143–147; 177–181; 239–243; 279–284; 321–325. With this system it is possible to vary at will the output of a generator pump, driven by a primary motor at constant speed, between zero and a maximum dependent on the pump capacity.

Applications of Hydraulic-Transmission Variable-Speed Drive to Machine Tools and Manufacturing Processes, W. Ferris. Am. Soc. Mech. Engrs., Advance Proofs, 1922, 34 pp. Abstracts in Mech. Eng., vol. 45, Apr. 1923, pp. 238–241, discussion p. 241; Machy., vol. 29, Feb. 1923, pp. 496–497. Describes and illustrates a number of applications of the "Oilgear" to machine-tool driving, broaching, hydraulic presses, etc.

Das Lentz-Getriebe, Wittfeld. Maschinenbau, vol. 1, 1922, pp. 497–503. Problems of speed reduction and reversal with reference to electrical and mechanical systems and the Lentz hydraulic system. Various applications to railway cars, types of ships, etc.

Foettinger Transformers on a Liner. Engineer, vol. 134, July 7, 1922, pp. 4–5, suppl. plate opp. p. 12. Abstract in Mech. Eng., vol. 44, Oct. 1922, pp. 668–669.

Front Wheel Drive Truck Features Gearset with Hydraulic Control, B. R. Dierfeld. Automotive Industries, vol. 48, Apr. 5, 1923, pp. 759–762. Design of Lippische truck chassis now being produced in Germany.

Gasoline Switching Locomotive with Hydraulic Drive. Ry. Age, vol. 73, Aug. 19, 1922, pp. 323–326. Also in Ry. Mech. Eng., vol. 96, Sept. 1922, pp. 503–506. Abstract in Mech. Eng., vol. 44, Oct. 1922, pp. 666–667.

Hydraulic Power Transmission Gears, M. H. Sabine. Prac. Eng., vol. 65, 1922, pp. 151–154; 205–206; 221–222; 235–236. Abstract in Mech. Eng., vol. 44, 1922, pp. 320–321. Applications; particulars required for transmission and pump sets. Details of Williams-Janney, Carey pump, and Hele-Shaw systems.

Hydraulic Press with "Oilgear" Control. Am. Mach., vol. 55, 1921, p. 295.

Hydraulic Steering Gears, H. S. Howard. Am. Soc. Nav. Engrs., vol. 34, 1922, pp. 259–279. Gears fitted to the New Mexico, Tennessee, Maryland, and West Virginia. Diagrams.

Hydraulic Transmission, F. L. Martineau. Inst. Automobile Engrs., Proc., vol. 11, 1916–1917, pp. 223–258. Classification of transmission systems. Description of Hall, Janney, and Hele-Shaw transmissions.

Hydraulic Versus Electric Drive for Steel-Mill Auxiliaries, R. B. Gebhardt. Assn. Iron & Steel Elec. Engrs., Proc., 1919, pp. 85–96. Also in Engrs.' Club Phila., Jl., vol. 36, pp. 303–308. Applications to particular operations, including door hoists, furnace covers, elevators, manipulators, lifting tables, middle roll, balance shears, and intensifiers.

Oilgear—A Variable Speed and Feed Control System. Am. Mach., vol. 55, 1921, pp. 271–274. Abstract in Mech. Eng., vol. 43, Oct. 1921, p. 682–683.

Recent Types of Hydraulic Transmission Gear. Eng. & Ind. Management, vol. 7, Apr. 6, 1922, pp. 323–327. Describes Williams-Janney swash-plate gear, the Hele-Shaw transmission system, and the Constantinesco wave transmission gear.

Variable Speed Oil Transmission Gear. Engineering, vol. 114, Dec. 1922, pp. 800–801, and 804. Gear constructed by Oilgear Co., Milwaukee Wis.

WAVE TRANSMISSION

Dorman Wave Power Tools, Rock Drills, Rivetters, etc., for mining and shipbuilding. W. H. Dorman & Co., Stafford, England, 1920. Preface by Walter Haddon.

Hydraulic-Wave Transmission. Elec. Times, vol. 57, 1920, pp. 133–134. Wave and electrical transmission compared. Describes the Constantinesco system.

Romance of Wave Transmission, new world's industry for Britain, progress of great twentieth-century invention by a mining engineer. Reprinted from Eng. Suppl. of Overseas Daily Mail, Oct. 14, 1922.

Sur la Transmission de l'Énergie par les Vibrations de Liquides dans les Conduites, C. E. D. Camichel and A. Foch. Comptes Rendus, vol. 171, 1920, pp. 783–786. Authors claim initial pressures must be considerable and find Mr. Constantinesco's analogy between hydraulic and electric phenomena not theoretically correct.

Technische Schwingungslehre, Wilhelm Hort. Second Edition. J. Springer, Berlin, 1922.

Theory of Wave Transmission, George Constantinesco. Walter Haddon, 132, Salisbury Square, E. C. 4, London, 1922. A treatise on transmission of power by vibrations.

Wave Power Transmission, W. Dinwoodie. Paper read before Soc. of Engrs. Inc., 17, Victoria St., Westminster, S. W. 1, on Dec. 4, 1922.

Wave Transmission, a New and Sixth Method of Transmitting Power. Walter Haddon. Ed. 3, London, 1922 A descriptive pamphlet on the invention of G. Constantinesco.

Wave Transmission Patents. Walter Haddon, 132, Salisbury Square, London, 1922.

Trade-Association Activities

Trade Association Activities. Prepared by L. E. Warford and R. A. May, under the direction of Julius Klein, Director, Bureau of Foreign and Domestic Commerce. Government Printing Office, Washington, D. C. Flexible linen, 6 × 9 in., 368 pp., $0.50.

To increase the popular interest in the reorganization of the Department of Commerce, and to aid in the development of a definite program for the elimination of national waste, for the establishment of industrial research, the collection of economic information, and the promotion of foreign trade, the Department, in a comprehensive publication entitled Trade Association Activities, has focused attention on the possibilities of the organizations of producers or distributors of commodities or service, known as trade associations.

The volume is accredited to L. E. Warford and Richard A. May, directed by Julius Klein, Director of the Bureau of Foreign and Domestic Commerce under Secretary Hoover. Its preparation was undertaken jointly by the Bureau of the Census, the Bureau of Foreign and Domestic Commerce, and the Bureau of Standards, aided by a representative committee covering the many phases of trade-association activities.

Secretary Hoover, in an extended introduction, enumerates the various essential constructive services rendered by associations, and in summarizing states that if we are to have a comprehensive economic system, it seems the time has come when we should take cognizance of the necessities. The growing complexities of our industrial life, its shift of objective and service, require the determination of an economic system based upon a proper sense of rightful coöperation, maintenance of long-view competition, individual initiative, business stability, and public interest.

The book has an important purpose and is exhaustive, but a brief review of its contents would be inadequate. However, the following chapter headings are suggestive of the large and representative amount of material brought together: Statistics and Their Legal Aspects, Legislative Activities, Simplification and Standardization, Cost Accounting, Credit and Collective Activities, Trade Disputes and Ethics, Employee Relations, Insurance, Public Relations, Traffic and Transportation, Commercial and Industrial Research, The Government, the Department of Commerce, Organization and Administration of Associations, History, Directory of National and International Associations.

Bearing the stamp of the Government, the work is official, and from the representative method of its compilation it may be considered as authoritative. The price is nominal only, and every one engaged in industry and commerce owes it to himself to secure a copy from the Superintendent of Documents.

Applied Mechanics. By Alfred P. Poorman. Second edition. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 293 pp., diagrams, $2.75.

A textbook for undergraduate courses in engineering schools. Departs from the usual procedure by making extended use of the graphic method of solution and by presenting a large number of illustrative examples which have been solved in detail to show the relation between the principle which has been developed and the problem to which it applies. Several changes have been made in the new edition and the section on statics has been expanded.

By-Product Coking. By G. Stanley Cooper. Second edition. Benn Brothers, London, 1923. Cloth, 6 × 9 in., 192 pp., illus., diagrams, 12s 6d.

An English treatise which aims to supply the need for a textbook by giving an accurate, up-to-date account of the industry as it stands at present. Considers the nature and preparation of coking coals, the development of the by-product oven, plant operation, oven systems, machinery, the recovery of by-products and the utilization of gas. Intended primarily for students, but useful also to practical men.

Caratteristiche Costruttive Delle Turbine Idrauliche Negl' Impianti Attuali. By Guido Gambardella. Antonio Villardi, Milan, 1923. Paper, 7 × 10 in., 133 pp.

In this contribution to the literature of the hydraulic turbine, the author is concerned with the correlation of recent theory and current practice, and with a comparison between the results of calculation and those obtained by laboratory tests. Theoretical and experimental data furnished by various manufacturers are given and modern features in distribution and regulation are explained. The book is intended for students who wish to understand current manufacturing practices, for purchasers of turbines and for manufacturers.

Costing and Price-Fixing. By J. M. Scott-Maxwell. Issac Pitman & Sons, New York and London, 1923. Cloth, 6 × 9 in., 211 pp., illus., $2.

The purpose of this book is to give briefly the general principles of cost accounting and, in detail, a complete system applicable to a factory manufacturing a large variety of apparatus, relatively to its total output, the great bulk of which cannot be completed and put into stock, but can be only partly manufactured and must be completed after the receipt of the customer's order. Appropriate parts of the system will meet all the requirements of factories that produce finished products and sell from stock, while the complete system can also be applied to plants that work to order only. The principles and system have been used by the author in practice for the past fifteen years.

Dock and Harbour Engineer's Reference Book. By Brysson Cunningham. Second edition. Charles Griffin & Co., London; J. B. Lippincott Co., Philadelphia, 1923. Fabrikoid, 4 × 6 in., 319 pp., diagrams, tables, 9s.

The subjects considered in this book are harbor and dock construction; quay and dock walls and wharfs and their equipment; locks, graving and floating docks and their equipment; dredging and subaqueous rock removal; maritime canals, channel rectification and demarcation, and coast defense. The volume does not attempt to be complete. It is based on notes made for his own use

by the author, and touches only lightly on theoretical considerations, being more concerned with particulars of works actually carried out and with their cost.

Les Economies de Combustibles; Conduite Rationnelle des Foyers. By Pierre Appell. Gauthier-Villars et Cie., Paris, 1923. (Encyclopédie Léauté, 2e série.) Paper, 6 × 8 in., 341 pp., illus., diagrams, tables, 17 fr.

The purpose of this book is to call attention to the economies in the use of fuel possible in industry and to indicate the methods by means of which these savings may be realized. The author reviews the fuel situation in France, gives directions for investigating and choosing fuels, explains the phenomena of combustion and discusses methods for using fuel efficiently under boilers, in gas producers, and in furnaces. Methods of measurement and control are also considered. A bibliography and index are given.

Electric Furnace for Iron and Steel. By Alfred Stansfield. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 453 pp., illus., diagrams, tables, $5.

Instead of issuing a new edition of his Electric Furnace, Dr. Stansfield has decided to replace it by two new books, of which the present work, dealing with the use of the electric furnace in the metallurgy of iron and steel, is one. It is intended to give a reasonably complete account of the electric smelting of iron ores to make pig iron and the making of steel from metallic charges in electric furnaces.

The book consists of three parts. The first contains historical matter, an outline of ferrous metallurgy, and a brief account of the electrical supply needed for electric furnaces. The second part describes the electric smelting of iron ores for pig iron, the reduction of iron ores in the state of powder and the production of ferro-alloys. The third part treats of the production of iron and steel from metallic materials and the furnaces in use for these purposes. It also includes a chapter on the production of steel from ore and on electric welding.

Electrical Handling of Materials, vol. 4: Machinery and Methods. By H. H. Broughton. Ernest Benn, London, 1923. Cloth, 9 × 11 in., 334 pp., illus., diagrams, 50s.

This, the concluding volume of Mr. Broughton's useful treatise, has for its subject the machinery used for handling materials mechanically and the methods of handling and storing. The opening chapters describe elevators, conveyors, belt conveyors, automatic feeders, and ship hoists. Succeeding chapters are devoted to methods of handling various articles, especially, ore, coal, grain and similar bulk materials, and foodstuffs. Like the other volumes, this one deals broadly with the question of design and gives many examples that illustrate the present state of the art.

Elements of Machine Design. By Dexter S. Kimball and John H. Barr. Second edition. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., 446 pp., illus., tables, $4.

A discussion of the fundamental principles of design, intended primarily for students, but also, the authors hope, of interest to designers. The principal part of the work is devoted to the discussion of the more important details of machines, with a view of showing how theoretical considerations and equations are applied and modified in practice. The new edition has been thoroughly revised and the arrangement changed as a result of experience. A chapter on the balancing of machine parts has been added.

Financial and Operating Ratios in Management. By James H. Bliss. Ronald Press Co., New York, 1923. Cloth, 6 × 9 in., 396 pp., tables, $6.

In every branch of industry there are certain characteristic financial and operating ratios, depending upon the nature of its activities. The aim of this book is to develop certain standard ratios for the use of managing executives in securing more effective control of the finances and operations of their business.

Part 1 of the book considers the various ratios and turnovers which should be noted and compared; explains how they are computed and their bearing on the general problem. Part 2 contains tables compiled from published reports of representative industries, with explanations. These statistics afford standards enabling a company to compare its own statistics with standards within the industry and thus gage its competitive position. The book also aims to show the methods by which a concern may prepare standards in its own line.

Hydraulics for Engineers and Engineering Students. By F. C. Lea. Fourth edition. Edward Arnold & Co., London, 1923. Cloth, 6 × 9 in., 594 pp., illus., tables, $6.

Dr. Lea's book is intended as a reference book for practicing engineers and as a textbook for serious students. He attempts to deal with the subject in a wider sense than is done in most textbooks, to embody the results of the latest experimental research on the subject, and to give sufficient details to indicate the methods used in obtaining those results. This edition has been revised to include the latest experiments. The original chapter on turbines has been much enlarged and that on pumps has been divided into two chapters.

Die Leistungssteigerung von Grossdampfkesseln. By Friederich Münzinger. Julius Springer, Berlin, 1922. Paper, 6 × 9 in., 163 pp., illus., diagrams, tables, $1.

An active experience in planning and operating large boiler plants during the last ten years has led the author to certain opinions concerning methods for increasing the output and economy of large steam generators and to an appreciation of various difficulties that have had to be overcome. The results of his practical work are set forth in the present volume, which discusses the ways by which large boiler plants may attain greater economy. Special attention is paid to the influence of accessory apparatus. The concluding chapter considers possible future developments.

Mechanisms of Machine Tools. By Thomas R. Shaw. Henry Frowde and Hodder & Stoughton, London, 1923. (Oxford Technical Publications.) Cloth, 9 × 11 in., 351 pp., illus., diagrams, $14.

In the present work Mr. Shaw endeavors to place on record many of the essential principles which have a place in machine-tool design. The book opens with an account of the evolution, types and functions of machine tools, in which several examples of early design are shown, accompanied by later designs showing the changes. The materials are then discussed briefly. The remainder of the book discusses many of the more important mechanisms: gearing, frames, bearings, power transmission, reverse motions, controlling, tripping, indexing and locking devices. These, as far as possible, have been grouped as separate units, distinct from any machine, so that the reader may analyze the different methods in use for a single operation. The volume is unusually attractive in make-up.

Modern Ironfoundry. By Joseph G. Horner. Henry Frowde, & Hodder & Stoughton, London, 1923. Cloth, 6 × 9 in., 255 pp., illus., $5.

The work of an experienced founder, this book is intended for apprentices and young men who wish an insight into practical methods. Cupolas and their working, fans, blowers and tools are described; methods of molding are explained and the causes of faults in casting are shown. There are chapters on flywheel, and cylinder molding, on machine molding and die casting, as well as one on foundry design and equipment.

Le Moteur Humain et les Bases Scientifiques du Travail Professionel. By Jules Amar. Second edition. Dunod, Paris, 1923. Cloth, 5 × 7 in., 690 pp., illus., tables, 45 fr.

Amar's book is a study of the mechanism of man as a motor, and of the way this motor works. It attempts to present all the physiological and physical data available for the scientific study of labor and for determining the efficiency of human work. Although the war has interfered seriously with scientific research during the nine years that have elapsed since the first edition appeared, some interesting investigations have been made, which have been incorporated in the new edition. New material is given on nutrition, physical training, locomotion, and on the measurement of sense perception, as well as on experimental methods.

Motor Boats. By F. Strickland. Isaac Pitman & Sons, London and New York, 1923. Cloth, 5 × 7 in., 116 pp., illus., $1.

A concise review, in non-technical language of the development and construction of motor boats, of the principles of the marine motor, of its advantages over the steam engine, and of its possible future development.

Power Plant Machinery, vol. 1; Mechanism of Steam Engines. By Walter H. James and Myron W. Dole. Second edition. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., 277 pp., illus., diagrams, $3.

In revising their textbook on the Mechanism of Steam Engines the authors decided to expand the work into a general discussion of the principal machines used in a steam power plant; of this work the present book becomes volume one. It is an elementary treatise on the kinematics of reciprocating steam engines and steam turbines, planned for students who take up the subject after a course in the elements of mechanism and before they study the theory and practice of heat engineering. An effort has been made to present the subject so that the beginner will understand the mechanical principles on which the engine operates, with special reference to the valve gear and governing devices, and the various diagrams used to study them. The aim is to treat these questions logically and concisely, yet with sufficient detail to make the principles easily understood.

Radiotelegraphie et Radiotelephonie a la Portée de Tons. By G. Malgorn. Gauthier-Villars et Cie., Paris, 1923. Paper, 6 × 9 in., 231 pp., illus., diagrams, 10 fr.

Most of the books on radio telegraphy and telephony have been written for those experimenters, amateur or professional, who wish to construct or assemble radio stations. The present writer addresses himself to that larger class of persons who purchase commercial radio sets ready for use, and who are interested only in understanding the principles of the apparatus and in learning how to use it most effectively. The book explains the theory of radio, the functions of the various parts of the receiving set, and supplies practical information on the operation and maintenance of the apparatus.

Wood-Preserving Terms. By Ernest F. Hartman and E. F. Paddock. Protexol Corporation, New York, 1922. Paper, 6×9 in., 85 pp., $1.

A useful glossary of terms used by wood preservers, including chemical, pathological and engineering terms, as well as those which are merely industrial. The definitions frequently are encyclopedic in fullness and accompanied by references to the literature, so that the pamphlet forms a convenient reference work.

Test Code for Locomotives

(Continued from page 610)

Coal and Rate of Combustion:

(32) Coal fired, total .... lb.
- (a) Dry coal fired, total .... lb.
- (b) Combustible by analysis, total .... lb.

(33) Coal as fired per hour .... lb.
- (a) Coal as fired per hour per sq. ft. of grate surface .... lb.
- (b) Coal as fired per hour per cu. ft. of firebox volume .... lb.
- (c) Dry coal fired per hour .... lb.
- (d) Dry coal fired per hour per sq. ft. of grate surface .... lb.

Quality of Steam:

(34) Quality of steam in dome .... per cent
- (a) Superheat of steam in branch pipe .... deg. fahr.

Water and Steam:

(35) Water evaporated, total .... lb.
- (a) Water delivered to boiler .... lb.
- (b) Weight of water in boiler at start of test minus weight of water in boiler at close of test, (plus or minus) .... lb.
- (c) Boiler correction .... lb.
- (d) Water losses .... lb.
- (e) Moist steam used at auxiliaries, calorimeter, safety valve, steam leaks, etc., total .... lb.
- (f) Superheated steam used or lost before reaching the engine cylinders, total .... lb.

Evaporation:

(36) Steam to superheater per hour .... lb.
- (a) Moist steam per hour .... lb.
- (b) Heat transfer across water-heating surface per hour (units of evaporation) .... 1000 B.t.u.
- (c) Heat transfer across superheating surface per hour (units of evaporation) .... 1000 B.t.u.

(37) Total heat transfer per hour (units of evaporation) ... 1000 B.t.u.
- (a) Heat transfer per hour per sq. ft. of heating surface (units of evaporation) .... 1000 B.t.u.

(38) Units of evaporation per pound of coal as fired .... 1000 B.t.u.
- (a) Units of evaporation per pound of dry coal .... 1000 B.t.u.

(39) Superheated steam per hour .... lb.

(40) Superheated steam per pound of coal as fired .... lb.
- (a) Superheated steam per pound of dry coal .... lb.
- (b) Superheated steam per hour per sq. ft. of heating surface .... lb.

(41) Efficiency of the boiler and furnace (heat absorbed by boiler) .... per cent

Engine Performance

(42) Steam delivered to the engines per hour .... lb.
- (a) Coal-as-fired equivalent of the water and steam losses .... lb. per hr.
- (b) Dry-coal equivalent of the water and steam losses .... lb. per hr.

Events and Pressures from Indicator Diagrams, Average:

(43) Mean effective pressure .... lb. per sq. in.
- (a) Cut-off .... per cent of stroke
- (b) Steam-chest pressure .... lb. per sq. in.
- (c) Initial pressure .... lb. per sq. in.
- (d) Pressure at cut-off .... lb. per sq. in.
- (e) Least back pressure .... lb. per sq. in.

Indicated Horsepower:

(44) Indicated horsepower .... i.hp.
- (a) Right side, head end .... i.hp.
- (b) Right side, crank end .... i.hp.
- (c) Left side, head end .... i.hp.
- (d) Left side, crank end .... i.hp.

(45) Coal as fired per i.hp. per hour .... lb.
- (a) Dry coal per i.hp. per hour .... lb.

(46) Steam per i.hp. per hour .... lb.
- (a) B.t.u. of coal consumed per i.hp. per hour ....

General Locomotive Performance

Drawbar Horsepower:

(47) Drawbar horsepower .... d.hp.
- (a) Average drawbar pull .... lb.
- (b) Maximum drawbar pull .... lb.

(48) Coal as fired per d.hp. per hour .... lb.
- (a) Dry coal per d.hp. per hour .... lb.
- (b) Coal as fired per 100 ton-miles .... lb.
- (c) Coal as fired per car-mile .... lb.
- (d) Dry coal per 100 ton-miles .... lb.
- (e) Dry coal per car-mile .... lb.

(49) Steam per d.hp. per hour .... lb.
- (a) B.t.u. consumed by engine per d.hp. her hour ....
- (b) Steam per 100 ton-miles .... lb.
- (c) Steam per car-mile .... lb.

Efficiency:

(50) Indicated horsepower minus drawbar horsepower .... hp.
(51) Ratio of d.hp. to i.hp. .... per cent
(52) Efficiency of the locomotive .... per cent

Endurance-Test-Data Interpretation

(Continued from page 581)

after a certain length of time. Repeating the experiment with another crankshaft identical in every respect and made by the same concern, it would be found that the life would be very different from that of the first one. This was true of practically every manufactured product.

Failure of a steel part always started at a definite point, and upon examination it would be found that it was due to some small defect such as porosity or the presence of slag; for there was no steel that did not contain slag, although in most cases it was present in such minute quantities that it could be detected only by a high-power microscope.

Those purchasing tungsten lamps, ball bearings, gears and the like wanted to know how long they would last under certain conditions and would select those with the longest life because they would be cheaper in the end and safer. Tests had to be repeated many times in order to get comparative results on which to base the endurance and safety of a product.

The curves given in the paper would prove of value to the manufacturer in that they would reveal to him the amount of dispersion, which he could then reduce by painstaking inspection.

The reason why failures occurred was not always clear; it was known in some cases, but not in all. He would emphasize the fact that every endurance test should be run to a definite end point; if possible, to the point where failure started.

THE ENGINEERING INDEX

Registered United States Great Britain and Canada

Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 113-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIR FURNACES

Fuel-Oil-Burning. Using Fuel Oil in Air Furnaces, A. V. Landschoot. Iron Trade Rev., vol. 73, no. 9, Aug. 30, 1923, pp. 599–604, 2 figs. Proper combustion, close control of heat, attention to charge, and regulation of time element are factors in operation of oil-fired malleable-iron melting units. From paper read at Am. Foundrymen's Assn. convention.

AIRSHIPS

ZR-1. Building the Large Navy Dirigible ZR-1, F. E. Schmidt. Am. Mach., vol. 59, no. 10, Sept. 6, 1923, pp. 367–371, 9 figs. Outline of problem in designing and building huge airship; special machine for drilling holes spaced within two thousandths of an inch; machining duralumin.

AUTOMOBILES

Wheels. The Spring Wheel, C. P. Schwarz. Automobile Engr., vol. 13, no. 179, Aug. 1923, pp. 238–242, 18 figs. Inquiry into design and commercial possibilities; described as wheel having yielding or resilient elements intended to render road shocks harmless.

BEARINGS, BALL

Contact Area of Ball and Plate. The Contact Area of an Elastic Sphere When Compressed Between Flat Elastic Plates, John Goodman. Engineering, vol. 116, no. 3005, Aug. 3, 1923, p. 133, 4 figs. Methods of ascertaining area in contact between a steel ball and steel plates, and results of tests.

BEARINGS, THRUST

Michell. An Air Lubricated Michell Bearing. Engineering, vol. 116, no. 3007, Aug. 17, 1923, p. 203, 3 figs. Notes on model constructed by Albert Kingsbury, consisting of two parts, a solid collar about $5^1/_8$ in. in diameter and 1 in. thick and weighing about $5^3/_4$ lb., and a baseplate or stand on which are mounted three Michell pads, pivoted behind their centers of figure in accordance with Michell principle.

BOILER PLANTS

Economical Operation of. New Mac-Sim-Bar Boiler Plant Saves $100,000 per Year. Power vol. 58, no. 10, Sept. 4, 1923, pp. 352–356, 12 figs. How consumption of coal per ton of board has been reduced from 2200 lb. to about 1200 lb., production of board per 24 hours increased from 150 to 170 tons, and power-house payroll cut in two, at plant of Mac-Sim-Bar Paper Co., Otsego, Mich.

BOILERS

Pulverized-Coal-Fired. Powdered Coal Installation, Whitaker-Glessner Plant, Wheeling Steel Corp. Power, vol. 58, no. 9, Aug. 28, 1923, pp. 333–334, 4 figs. Describes powdered-coal boilers of new plant, and its equipment.

BRIQUETTING

Metal Turnings. Dust and Metal Briquetting. Iron Age, vol. 112, no. 8, Aug. 23, 1923, p. 475, 1 fig. De Gama process for recovery of metal turnings, blast-furnace dust and ore fines.

CASE-HARDENING

Steel. Carburization of Steel, B. F. Shepherd. Am. Soc. Steel Treating—Trans., vol. 4, no. 2, Aug. 1923, pp. 171–196, 21 figs. Study of continued use of carburizing compounds as it affects character of case produced; influence of increased carburizing temperature, effect of time variation, influence of time and temperature upon character of case, and relationship in carburized and hardened chrome-vanadium steel between scleroscope hardness, carbon content and penetrability as measured by Brinell method at different zones in case.

CAST IRON

Pearlitic. Pearlitic Cast Iron, O. Bauer. Iron Age, vol. 112, no. 7, Aug. 16, 1923, p. 412. New type of iron castings developed in Germany; use of hot-sand molds affects microstructure and properties. Abstracted and translated from Stahl u. Eisen, and discussed by Richard Moldenke.

CASTINGS

Testing Methods. New Testing Methods for Castings, E. Ronceray. Iron Age, vol. 112, nos. 7 and 8, Aug. 16 and 23, 1923, pp. 393–396 and 470–473, 20 figs. Discussion of elastic limit; modulus of elasticity; sound, compression and bar tests; comparisons with Brinell hardness; transverse and shearing tests recommended and tension and shock tests condemned. Paper presented to Inst. Brit. Foundrymen.

CHUCKS

Vacuum, Work-Holding. Holding Work by Vacuum, Charles O. Herb. Machy. (N. Y.), vol. 30, no. 1, Sept. 1923, pp. 12–15, 8 figs. Describes chucks, developed by Crescent Pump Co., Detroit, Mich., that utilize vacuum for holding large quantities of small pieces made of either ferrous or non-ferrous metals, and non-metallic work such as rubber, fabric, wood or glass, during machining operations.

CONDENSERS, STEAM

Testing. Testing Jet Condensers, L. Long. Power, vol. 58, no. 8, Aug. 21, 1923, pp. 293–296, 1 fig. Means of locating faults. Eroded or plugged injection nozzles, high temperature of incoming water, corrections for vacuum and barometer readings, and other points which come up in jet condenser testing, are described.

CORES

Mixtures for, Reducing Cost of. Cheapens Core Sand Mixtures, C. S. Koch. Foundry, vol. 51, no. 16, Aug. 15, 1923, pp. 665–670 and 685, 9 figs. Experiments said to indicate costs in shops making light steel castings can be reduced by using heap sand in cores; tensile-testing strength determines strength of dried mixtures. Paper presented before Am. Foundrymen's Assn.

CRANES

Gantry. Improved Gantry Cranes for the Port of Hamburg, Germany, E. Krahnen. Eng. News-Rec., vol. 91, no. 8, Aug. 23, 1923, pp. 296–297, 5 figs. Describes combination swinging and traveling cranes which increase cargo-handling facilities.

DIE CASTING

Problems in. Solving Die-casting Problems. Machy. (N. Y.), vol. 30, no. 1, Sept. 1923, pp. 51–52, 5 figs. Information obtained at plant of Atlas Die Casting Corp., Worcester, Mass., regarding problems of constructing die so as to produce casting with least difficulty, and obtaining accuracy in sinking die impression.

DIESEL ENGINES

Fuel-Consumption Test. Test of Diesel Fuel Consumption, W. B. Gregory. Power, vol. 58, no. 8, Aug. 21, 1923, pp. 285–286, 2 figs. Account of test undertaken for City of Crowley, La., to determine whether guarantees made by builders had been met.

GEARS

Steel for. Gear Steel. Automobile Engr., vol. 13, no. 179, Aug. 1923, pp. 232–237, 13 figs. Investigation of factors governing wear.

GRINDING MACHINES

Centerless. New Centerless Grinder. Iron Age, vol. 112, no. 8, Aug. 23, 1923, pp. 479–480, 3 figs. Shoulder and straight cylindrical work ground rapidly; 16 feed variations provided.

HYDROELECTRIC DEVELOPMENTS

California. Hydro-Electric Developments in California. Engineering, vol. 116, no. 3007, Aug. 17, 1923, pp. 210–212. Details of construction program which will bring about complete electrification of whole of North American Pacific Coast from San Diego to Vancouver, and in which American and Canadian enterprise will coöperate.

Hydro-Steam Electric Generation. The Paradox of Hydro-Steam, George Holmes Moore. Eng. News-Rec., vol. 91, no. 9, Aug. 30, 1923, pp. 354–356, 5 figs. Analysis to show that energy generated by combined steam and hydro prime movers can cost less than either one separately.

INSPECTION

Contour Measuring Projector. New Projector Measures Wide Range of Precision Parts. Automotive Industries, vol. 49, no. 8, Aug. 23, 1923, pp. 364–367, 9 figs. Describes contour measuring projector, an instrument developed by Bausch & Lomb Optical Co., for visual inspection of screw threads, forms of gear and cutter teeth, and other parts; accuracy of 0.0001 in. can be attained; separate attachments make photographs.

LABORATORIES

Locomotive. Locomotive Testing Laboratory, Robert H. Moulton. Machy. (N. Y.), vol. 30, no. 1, Sept. 1923, p. 6, 2 figs. Notes on equipment of laboratory of Univ. of Ill.; unique locomotive which runs under full steam and at same time remains stationary, is part of equipment.

LOCOMOTIVES

Repair. Repairing Locomotives in a Machine-Tool Shop. Am. Mach., vol. 58, no. 25 and vol. 59, nos. 1 and 9, June 21, July 5 and Aug. 30, 1923, pp. 893–896, 11–13 and 317–319, 26 figs. June 21: Shop located on main line; cranes and other handling equipment; all classes of locomotive repairs handled. July 5: Rod, valve and motion work; worn guides, crossheads and pistons built up with manganese bronze; welding broken frames. Aug. 30: portable floor and cylinder boring machines; repairing driving boxes; minor boiler repairs.

MOTOR TRUCKS

6-Ton. 6-Ton Motor Vehicle for Service at High Altitudes. Engineering, vol. 116, no. 3005, Aug. 3, 1923, p. 140, 14 figs. on supp. plate. Describes vehicle built by Halley's Industrial Motors, Ltd., Glasgow, for use at tin mines of Bolivia; has to work at altitudes of from 11,000 ft. to 15,800 ft. above sea level; six-cylinder engine of 5-in. bore and $6^1/_2$ in. stroke, which gives Treasury rating of 60 hp. and normal running speed is 1000 r.p.m.

OIL ENGINES

Kerosene. Two-Cylinder Parafin Lighting Set. Engineer, vol. 136, no. 3528, Aug. 10, 1923, p. 158, 2 figs. New Type of oil-engine-driven electric lighting set, having capacity of 10 kw. at 105 volts, and driven by engine similar to those made by same firm for motor boats.

PUMPING PLANTS

Bristol, England. The Cheddar Pumping Station. Engineering, vol. 116, no. 3007, Aug. 17, 1923, pp. 199–201, 3 figs. Data on station recently installed by Bristol Waterworks Co. to increase quantity of water available; contains three main pumping sets each consisting of a 5-stage Mather & Platt turbine pump geared to a 2-cylinder Ruston & Hornsby horizontal cold-starting airless-injection oil engine.

RAILWAY REPAIR SHOPS

Special Tools for. Special Tools in the Great Northern Shop, Frank C. Hudson. Am. Mach., vol. 59, no. 10, Sept. 6, 1923, pp. 351–353, 6 figs. Describes devices that save labor and expense in a railway repair shop.

SEMI-STEEL

Chemical Control. The Role of Chemistry in Semi-Steel, J. E. Bock. Iron Age, vol. 112, no. 7, Aug. 16, 1923, pp. 397–398. Chemical control of both raw materials and finished product necessary; role of combined carbon; effect of other elements.

Mechanical Characteristics. Mechanical Characteristics of Casting, Albert Portevin. Iron Age, vol. 112, no. 10, Sept. 6, 1923, pp. 610–614, 8 figs. Examination of semi-steel tensile and compressive strength, elasticity and shearing resistance, compared with its hardness; considers also semi-hard steel. Translation.

STEAM ACCUMULATORS

High-Pressure. The Steam Accumulator and Its Applications. Power vol. 58, no. 9, Aug. 28, 1923, pp. 322–326, 8 figs. Describes construction of high-pressure accumulator and shows how weights, capacities, etc., are figured; some possible applications.

STEAM TURBINES

Disks, Stresses in. Rotating Disks of Conical Profile, B. Hodkinson. Engineering, vol. 116, no. 3009, Aug. 31, 1923, pp. 274–275, 3 figs. Gives table which forms basis of practical method described of determining stresses in such disks; points out that for any given loading boundry stresses can without any simplification or further assumption, be put in by trial, easily, and with ample accuracy, and this complete solution obtained for practical disk.

Multiple-Exhaust, Tests on. Tests of the 15,000-Kw. "Multiple Exhaust" Turbine at Dalmarnock Engineering, vol. 116, no. 3009, Aug. 31, 1923, pp. 273–274, 2 figs. Results achieved with 15,000-kw.–18, 750-kw. turbine at Glasgow Corp. Power Station, Dalmarnock, where R. B. Mitchell had the enterprise to install this large unit in which K. Baumann's multiple exhaust was embodied.

STEEL CASTINGS

Battleship Turret Track. Steel Turret Track Castings, S. W. Brinson. Foundry, vol. 51, no. 16, Aug. 15, 1923, pp. 645–648 and 664, 8 figs. Methods and equipment adopted in Navy Yard foundry for molding, pouring and annealing battleship castings designed to meet severe chemical and physical specifications.

Heat Treatment. Heat Treating Improves Castings, A. E. Lorenz. Iron Trade Rev., vol. 73, no. 8, Aug. 23, 1923, pp. 534–535, 2 figs. Excellent results obtained with chrome-nickel steels; treatment exaggerates good and bad properties of material; more research on special alloy steel castings needed as their demand increases. (Abstract.) Paper presented before Am. Foundrymen's Assn.

Preliminary Strengthening Treatment. Making Steel Castings Tough as Forgings, L. R. Mann. Iron Age, vol. 112, no. 7, Aug. 16, 1923, 425–426, 2 figs. Preliminary treatment to produce homogeneity in austenite essential to ideal metal structure; alloying elements may be used to advantage.

STEEL, HEAT TREATMENT OF

Annealing Sheet Steel. The Annealing of Sheet Steel, Francis G. White. Am. Soc. Steel Treating—Trans., vol. 4, no. 2, Aug. 1923, pp. 121–139 and 216–217, 18 figs. Discusses annealing of low-carbon sheet steel from mill standpoint; grain growth caused by slow cooling rate from annealing temperature is shown in photomicrographs; furnace designs, temperature curves, and stamping tests; outline of general practice in one plant.

TOOLS

Hardened, Production of. Tool Room Troubles, A. H. Kingsbury. Am. Soc. Steel Treating—Trans., vol. 4, no. 2, Aug. 1923, pp. 197–215. Review of various factors involved in production of hardened tools; discusses marking of various grades of steel, design, machining strains, heat treating, proper hardening range, quenching speeds, drawing, soft spots and similar troubles, vanadium as alloying element, and grinding practice.